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AUTHOR Greenstone, Sid; Smith, Murray
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ABSTRACT

Selected materials needed to teach an astronomy unit as well as suggested procedures, activities, ideas, and astronomy fact sheets published by the Manitoba Planetarium are provided. Subjects of the fact sheets include: publications and classroom picture sets available from the National Aeronautics and Space Administration and facts and statistics about the sun, moon, inner planets, outer planets, satellites of the solar system, planetary conjunction of 1981, meteors and meteor showers, comets, the Milky Way, quasars and pulsars, unidentified flying objects (UFO's), and activities of the Manitoba Planetarium. Instructions are provided for making constellation slides and constellation cans, with suggested student activities. Charts of constellations which may be duplicated or used to prepare overhead transparencies are also provided. Additional activities focus on constellation positions, earth rotation/revolution, planets and the zodiac, cosmic calendar, survival on the moon, scale diagrams of the solar system, ellipses, planetary orbits, reading from a metric ruler, what happens to a spinning ball, color/temperature relationship of stars, distance measuring devices, and astrolabes. Word search activities, astronomy books and audio-visual materials available from the Manitoba Education Library and 16-mm films available from the School Film Services, and information for observing astronomical phenomena ("Sky Watch") are included. (JN)

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JUNIOR HIGH ASTRONOMY

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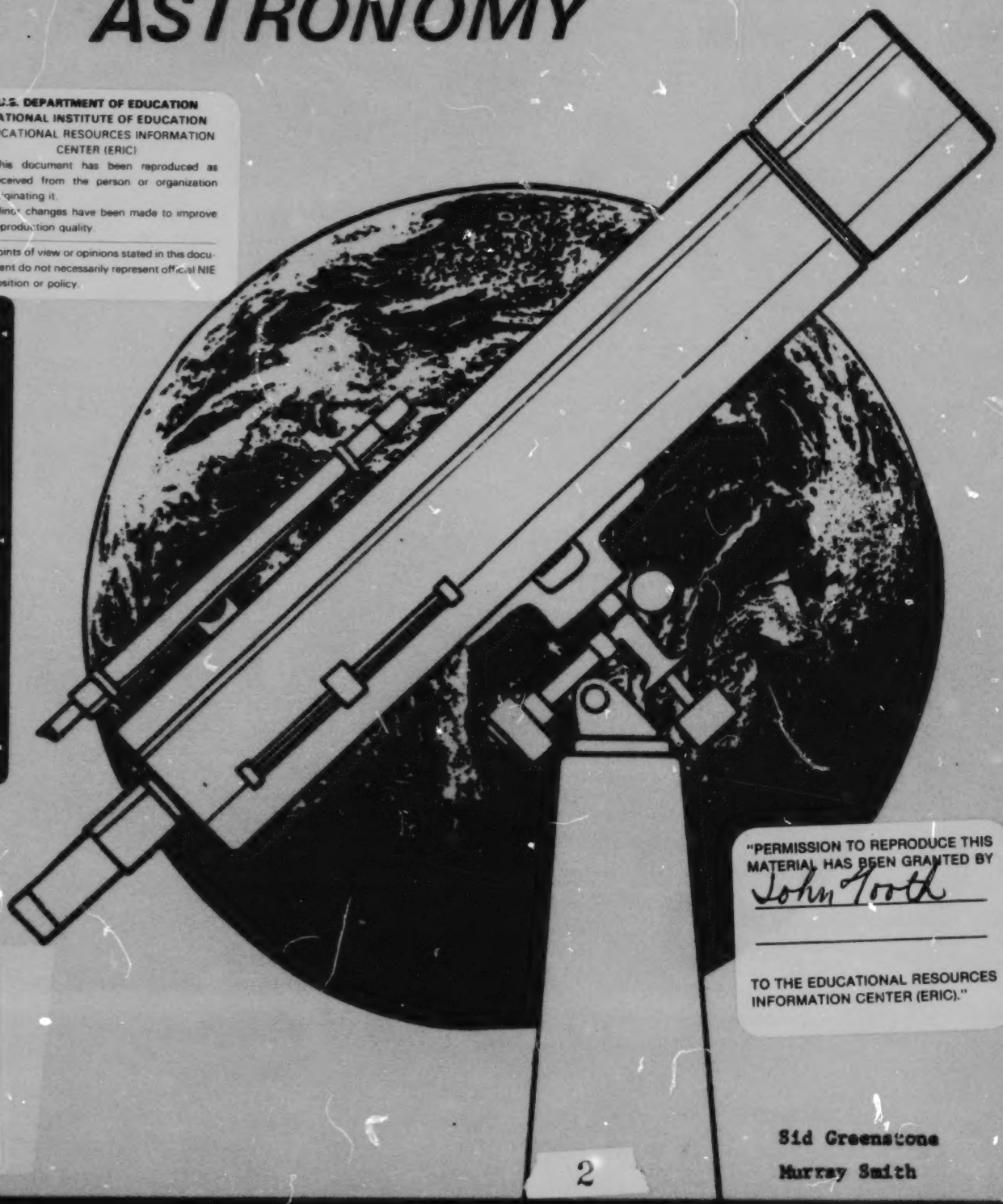

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Sid Greenstone
Murray Smith

MANITOBA
DEPARTMENT OF EDUCATION
Program Development
Curriculum Services Branch
Telephone: 786-0317
Robert Fletcher Building
411 — 1181 Portage Avenue
Winnipeg, Manitoba
R3G 0T3

TO THE INSERVICE PARTICIPANTS:

The following booklet is presented to you in conjunction with a workshop on astronomy.

This booklet was designed as a hands-on approach to the field of astronomy. The focus is methodology coupled with essential theory. Our aim is to provide you with the materials you need to teach an astronomy unit to your students as well as suggested procedures, activities and ideas. Astronomy fact sheets have been gathered for you and are interwoven into each activity.

We hope that this inservice will be useful to you and to your students.

Thank you for your interest. If you have any questions and/or comments please, do not hesitate to contact us.

Yours truly,

Sid Greenstone

Murray R. Smith

PS: We can be contacted at the following places:

Sid Greenstone
c/o Faculty of Education
University of Manitoba
WINNIPEG, Manitoba
R3T 2N2
Phone: 1-474-9741

Murray R. Smith
Frontier School Division #48
121-1st Street S.W.
DAUPHIN, Manitoba
R7N 1M9
Phone: 1-638-6839

MANITOBA PLANETARIUM

Astronomical Information Sheet

NASA EDUCATIONAL PUBLICATIONS

The following is a partial list of Educational publications available from the National Aeronautics and Space Administration, Washington, D.C. These are ideal sources of pictures and resource material for school projects on space and space exploration. The publications should be ordered from:

Superintendent of Documents
U.S. Government Printing Office,
WASHINGTON, D.C. 20402

Payment may be made by cheque or money order payable in U.S. funds. Make sure to include the publication number in your order.

EP-51 SPACE PHYSICS AND ASTRONOMY - A summary of progress in studies of Earth's radiation belts, the magnetic shell around the Earth, the solar wind, the Sun and Earth weather, meteorites, cosmic rays and the role of spacecraft as "robot star gazers". 22 pages/45¢.

EP-54 NASA SPACECRAFT - The present family of NASA spacecraft. All types are discussed, some small, some large; some spin-oriented, some accurately attitude-controlled; some manned, some automated; some free in space until they expire, other commanded to return to Earth or to land on the Moon. 26 pages/50¢.

EP-57 MAN IN SPACE - A chronicle of the Mercury, Gemini and Apollo Manned Space Flight Programs. 30 pages/85¢.

EP-71 "IN THIS DECADE...." - Mission to the Moon - This "pre-launch" booklet outlines the complex steps leading to a manned lunar landing. The many and varied areas of research and development conducted by the National Aeronautics and Space Administration are illustrated. In colour. 48 pages/$1.45.

EP-72 LOG OF APOLLO 11 - The greatest voyage in the history of mankind, the journey of Apollo 11, is documented in this booklet. In colour. 12 pages/35¢.

EP-84 SATELLITES AT WORK - Spacecraft for communications, geodesy and weather observations are described. The new area for working satellites of surveying of Earth resources is also covered. 28 pages/$1.00.

EP-94 APOLLO 15 at Hadley Base - The Lunar Voyage of Endeavour and Falcon is narrated with full colour illustrations and a traverse map. 32 pages/$1.35.

EP-91 APOLLO 14: SCIENCE AT FRA MAURO - Exploration of the upland Fra Mauro area of the moon incorporated the most extensive scientific observations in manned lunar exploration up to that time. The story is presented in text, a traverse map and spectacular colour photographs. 48 pages/$1.25.

EP-06 SPACE SHUTTLE - This publication describes the space shuttle program and augments the material on wall poster. NF-44. /70¢.

EP-97 APOLLO 16 AT DESCARTES - A comprehensive look at the flight of Apollo 16, covering the highlights of the mission, including many detailed colour photographs. /$1.35.

EP-100 APOLLO - Commemorative Book summarizes the historic manned lunar landing program and features in colour some of the best photographs from each Apollo mission. 64 pages/$2.65.

EP-118 OUR PRODIGAL SUN - The dynamic Sun, its characteristics observed and measured by spacecraft, is proving more complex and fascinating than ever; especially for a world anxious to use its store of energy. 14 pages/35¢.

EP-120 QUASARS, PULSARS, BLACK HOLES AND HEAO'S - Astrophysics, the physics of the stars, takes on exciting new dimensions as the result of recent discoveries in the visible high-energy universe where physical processes are so powerful they cannot be reproduced on Earth. 2[illegible] pages/80¢.

EP-121 NASA AND ENERGY - NASA is developing ways to tap the heat and light of the Sun to meet the nation's future energy requirements. But that is only part of the story. NASA engineers also are working on clean, renewable fuels; wind-generated electricity; finding new fuel deposits; and exploring a variety of conservation techniques. 16 pages/35¢.

EP-32 LEARNING ABOUT SPACE CAREERS - Provides upper elementary students with ideas and suggestions for things to do to help with a career choice. It includes information about the space industry and the world of work. 24 pages/25¢.

The following are publications in the NASA FACTS Series. They contain condensed information on a NASA Program or a related area of research. Some are in the form of wall posters.

NF-27 LIVING IN SPACE - A description of the life support system devised by science and industry to enable spacecraft crews to remain in space for extended periods of time in an Earth-like environment. 12 pages/30¢.

NF-33 SATURN V - Colour wall poster depicting Saturn V, America's largest rocket vehicle, which launches the Apollo spacecraft. /25¢.

NF-40 JOURNEY TO THE MOON - A colour wall poster depicting manned space flight to the Moon, including landing on the Moon, re-joining the Apollo spacecraft, and the return to Earth. /60¢.

NF-43 SKYLAB - A colour wall poster describing in words and pictures NASA's first earth-orbiting space station - SKYLAB. /60¢.

NF-44 SPACE SHUTTLE - A colour wall poster similar to NF-43, but in this case illustrates NASA's reusable space vehicle, the SPACE SHUTTLE. /60¢.

S-2 SPACECRAFT TRACKING AND COMMUNICATION - Jr. High School - General Science - A Simplified description of the electonics communication bridges between Earth-based controllers and mission-performing manned and unmanned space-craft. /5¢.

S-4 THE COUNTDOWN - Elementary: General Science - Describes the activities and preparations that take place before, during and after the launching of a spacecraft. /5¢.

S-5 WEIGHTLESSNESS - Jr. High School: Physics - Weightlessness is explained by everyday experiences and simple experiments in this description of a complex phenomenon. /5¢.

S-6 SOLAR CELLS - High School: Physical Science - An explanation of the primary source of electrical power for the majority of NASA's unmanned space missions. /5¢.

S-7 ORBITS AND REVOLUTIONS - High School: Physics - A description of the physical and mathematical principles that govern the movement of one body about another in the environment of space. /10¢.

CLASSROOM PICTURE SETS

NASA PICTURE SET #1 - APOLLO - "IN THE BEGINNING...." - Seven 11" x 14" colour lithographs that illustrate highlights from the Apollo 8, 9, and 10 missions. /$1.85 per set.

NASA PICTURE SET #2 - MEN OF APOLLO - Five 11" x 14" colour lithogaphs that include portraits of the crews of Apollo, 7, 8, 9, 10 and 11. /$1.00 per set.

NASA PICTURE SET #5 - MAN ON THE MOON - One 16" x 20" colour lithograph that best illustrates man's moments of success, the first step in his conquest of space. /$1.00 per copy.

NASA PICTURE SET #6 - APOLLO 12 - Pinpoint landing on the Moon. Eight 11" x 14" colour lithographs and two 11" x 14" black and white lithographs illustrating man's return to the Moon. /$2.00 per set.

NASA PICTURE SET #7 - APOLLO 15 - Nine 11" x 14" colour lithographs illustrating the journey to the Moon of Endeavour and Faloon. /$2.10 per set.

MANITOBA PLANETARIUM
Astronomical Information Sheet

"A STAR CALLED SUN"

Our sun is one of a hundred billion stars that make up the giant whirlpool island universe we call the Milky Way Galaxy. It has been in existence for approximately five billion years and may last another five billion. We must consider this brilliant yellow orb in our daytime sky as a tremendous hydrogen bomb, the energy being produced as a result of a fusion process whereby hydrogen, the lightest known element is converted into helium. The sun slowly is evolving into a brighter, hotter star at present, but astronomers are uncertain as to eventual fate: will it continually expand into oblivion? By that time there will surely be no possibility of life on earth, for it will have grown extremely cold--or hot.

SOME FACTS ABOUT THE SUN

Layers	Corona, Chromosphere, Photosphere, core
Mean Distance From Earth	149,600,000 km.
Maximum Distance From Earth	152,083,000 km.
Minimum Distance From Earth	147,260,000 km.
Mass	333,400 Earth masses, or 2.0×10^{27} metric tons
Spectral Type	G2V
Diameter (Photosphere)	109.3 Earth diameters, 139,112 km.
Velocity with respect to the nearby stars	20 km/sec.
Mean Density	1.41 gm/cc
Gravity (at photosphere)	27.9 times that of earth
Visual Magnitude	-26.5
Rotation Period at Equator	24 days, 16 hours
Rotation Period at Poles	Approx. 35 days
Inclination of Pole to Ecliptic	7 degrees 10.5 minutes
Temperature of Photosphere	6000°C
Temperature of Core	14,000,000°C
Average Time Between Minimum and Maximum Numbers of Sunspots	11.1 years (extremes, 7-17 years)
Size of Sunspots	3,000 - 150,000 km; average size approx. 15,000 km.

MANITOBA PLANETARIUM

Astronomical Information Sheet

STATISTICS OF THE INNER PLANETS

	Mercury	Venus	Earth	Mars
Equatorial Diameter	4,865 km.	12,110 km.	12,756 km.	6,788
Closest Approach to Sun	45,992,200 km.	107,449,700 km.	147,070,400 km.	206,553,600 km.
Farthest Distance from Sun	69,803,500 km.	108,915,500 km.	152,065,900 km.	249,180,500 km.
Period of Revolution	88.0^{d}	224.7^{d}	365.26^{d}	687.0^{d}
Period of Rotation	$58^{d}\ 16^{h}$	243^{d} (Retro)	$23^{h}\ 56^{m}\ 04^{s}$	$24^{h}\ 37^{m}\ 23^{s}$
Length of Day	$175^{d}\ 20^{h}\ 24^{m}$	$117^{d}\ 01^{h}\ 09^{m}$	$24^{h}\ 00^{m}\ 00^{s}$ *	$24^{h}\ 39^{m}$ 25
Inclination of Orbit to Ecliptic Plane	7°	3.4°	0.0° *	1.8°
Inclination of Axis to Plane of Orbit	7° or less	174°	23.4°	24.0°
Mass (Earth = 1)	0.055	0.815	1.000 *	0.107
Density (Water = 1)	5.46	5.23	5.52	3.93
Surface Gravity (Earth = 1)	0.38	0.90	1.00 *	0.38
Composition of Atmosphere	Ionized atomic particles	Carbon dioxide, Ice Crystals	Oxygen, Nitrogen, water vapor	Carbon dioxide, Oxides of nitrogen
Temperature Range at Equator **	290°/700°K.	700° K. (?)	265°/330° K.	200°/290° K.
Albedo (% of Sunlight Reflected by Planet)	5.6%	76%	36%	16%
Synodic Period	116^{d}	584^{d}	—	780^{d}
Number of Satellites	0	0	1	2

*By Definition **T^{o} K. = $(T + 273)^{o}$ C.

MANITOBA MUSEUM OF MAN AND NATURE - PLANETARIUM
Astronomical Information Sheet

THE EARTH - OUR SPACE SHIP

Equatorial Diameter:	12,756 kilometers/7,927 miles
Polar Diameter:	12,714 kilometers/7,900 miles
Amount of Polar Flattening:	1/298.25 or 0.003353
Mass:	5.98×10^{21} metric tons
Mean Density:	5.52 grams/cubic centimeter (Water = 1,000)
Surface Gravity:	1.00 by definition (Jupiter = 2.64, Moon = 0.16).
Escape Velocity:	11.2 kilometers/second or 6.94 miles/second
Inclination of Equator to Plane of Orbit around Sun:	23.4 degrees
Mean Distance from Sun	149,600,000 kilometers/92,957,000 miles
Minimum Distance (Perihellon):	147,070,400 kilometers/91,404,800 miles
Maximum Distance (Aphelion):	152,065,900 kilometers/94,509,600 miles
Mean Orbital Velocity:	29.8 kilometers/second or 18.5 miles/second
Velocity of Escape from Solar System at Earth's Distance from Sun:	42.3 kilometers/second or 26.2 miles/second.
Length of Sidereal Day:	$23^h\ 56^m\ 04^s$ of mean solar time, relative to the fixed stars
Length of Solar Day:	$24^h\ 00^m\ 00^s$ by definition. $24^h\ 03^m\ 57^s$ of sidereal time
Length of Sidereal Month:	$27^d\ 07^h\ 43^m\ 12^s$ relative to the fixed stars
Length of Synodic Month:	$29^d\ 12^h\ 44^m\ 03^s$ new moon to new moon
Length of Sidereal Year:	$365^d\ 06^h\ 09^m\ 10^s$ relative to the fixed stars.
Length of Tropical Year:	$365^d\ 05^h\ 48^m\ 46^s$ vernal equinox to vernal equinox
Temperature Range at Equator:	265/330 degrees Kelvin or +20/+135 degrees Fahrenheit
Albedo (% of Reflected Sunlight):	36%
Composition of Atmosphere:	Oxygen, Nitrogen, Water vapor

Earth's Motion as a Member of the Solar System:

1. Sun's Local Motion - Direction: Toward the constellation Hercules
   - Velocity: 19.4 kilometers/second or 12.1 miles/second

2. Sun's Revolution in our Galaxy:

Distance to Centre:	30,000 light years/10,000 parsecs
Period of Revolution:	2.2 million years
Orbital Velocity:	260 kilometers/second or 160 miles/second

MANITOBA MUSEUM OF MAN AND NATURE - PLANETARIUM
Astronomical Information Sheet

THE MOON - OUR NEAREST NEIGHBOUR IN SPACE

In 1969, the moon became the first astronomical body to be visited by man. Many theories about the origin and nature of the moon were put to rest as a result of this and of subsequent visits through the end of 1972. The lunar rock samples and the data sent back by instruments deployed on the moon by the astronauts will continue to provide, for decades to come, information of the nature of the moon and on the origin of the solar system.

Mean Distance from Earth:	384,344 Kilometers/238,865 miles
Minimum Distance (Perigee):	356,334 Kilometers/221,463 miles
Maximum Distance (Apogee):	406,625 Kilometers/252,719 miles
Sidereal Period of Revolution:	$27^{d}\ 07^{h}\ 43^{m}\ 12^{s}$ relative to the fixed stars.
Synodic Period of Revolution:	$29^{d}\ 12^{h}\ 44^{m}\ 03^{s}$ new moon to new moon
Periods of Rotation:	Same as periods of revolution
Stellar Magnitude:	-12.7 at full moon (This is 40,000 times the brightness of a first-magnitude star).
Equatorial Diameter:	0.273 earth diameters/3,476 km./2,160 ml.
Degree of Polar Flattening:	Nil
Mass:	0.0123 earth masses/6.57×10^{19} metric tons
Average Density:	3.36 grams/cubic centimeter (water = 1.000)
Surface Gravity:	0.165 earth gravity (eg. 150 lb. weighs 25 lb)
Escape Velocity:	2.2 kilometers/second or 1.5 miles/sec.
Atmospheric Composition:	Nil
Temperature - Sunlit Side:	382° Kelvin/+230° Fahrenheit*
Temperature - Dark Side:	94° Kelvin/-289° Fahrenheit*
Albedo (1% of reflected sunlight):	8.6%
Inclination of Equator to Orbit:	6.7 degrees
Inclination of Equator to Plane of Solar System:	Variable: 18 to 29 degrees
Inclination of Orbit to Plane of Solar System:	5.15 degrees
Eccentricity of Orbit:	0.0549

*T^{o} Kelvin = $(T - 273)^{o}$ Celsius

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Astronomical Information Sheet

STATISTICS OF THE OUTER PLANETS

	Jupiter	Saturn	Uranus	Neptune	Pluto
Equatorial Diameter	142,749+	120,862+	46,993+	44,579+	5,600-12,900+
Closet Approach to Sun	740,670,224+	542,925,926+	2,734,690,313+	4,458,083,758+	4,423,742,739+
Furthest Distance from Sun	816,068,698+	1,506,473,283+	3,005,466,545+	4,535,875,842+	7,376,680,569+
Period of Rotation	$9^h50^m30^s$	10^h14^m	10^h49^m (Retro)	14 hours	$6^{dgh}16^m$
Length of Day	"	"	From 10^h49^m to 42 years	"	"
Period of Revolution	11.86 yrs.	29.46 yrs.	84.01 yrs.	164.8 yrs.	247.7 yrs.
Inclination of Orbit	1.3°	2.5°	0.8°	1.8°	17.2°
No. of Satellites	13 or 14	10	5	2	1
Mass (Earth=1)	318.0	95.2	14.6	17.3	0.05
Density (Water=1)	1.33	0.69	1.56	2.27	4
Surface Gravity (Earth=1)	2.64	1.13	1.07	1.41	0.3
Composition of Atmosphere	Hydrogen Helium Neon Methane and Ammonia	Hydrogen Helium Neon Methane and Ammonia	Hydrogen Helium Methane	Hydrogen Helium Methane	Undetectable
Temperature Range at Equator	-157°	-171°C	-184°C	-198°C	-212°C
Albedo (% of sun-light reflected)	73%	76%	93%	84%	14%
Synodic Period	399^d	378^d	370^d	367^d	367^d
Inclination of Axis	3°	27°	98°	29 1/2°	?

Distances in Kilometers +

MANITOBA PLANETARIUM
Astronomical Information

SATELLITES OF THE SOLAR SYSTEM

Designation		Diameter km	Distance from Planet km	Period d h m	Discovery
Earth 1	Moon	3,476	384,000	27 07 43	--------
Mars 1	Phobos	23*	9,000	00 07 39	1877, Hall
Mars 2	Deimos	13*	23,000	01 06 18	1877, Hall
Jupiter 5	Amalthea	(160)	180,000	00 11 57	1892, Barnard
Jupiter 1	Io	3,660*	422,000	01 18 28	1610, Galileo
Jupiter 2	Europa	2,880	671,000	03 13 14	1610, Galileo
Jupiter 3	Ganymede	5,460*	1,070,000	07 03 43	1610, Galileo
Jupiter 4	Callisto	4,460	1,884,000	16 16 32	1610, Galileo
Jupiter 13	Leda	(5)*	10,200,000*	210 15 --*	1974, Kowal
Jupiter 6	Himalia	(100)	11,477,000	250 14 --	1904, Perrine
Jupiter 7	Elara	(40)	11,738,000	259 16 --	1905, Perrine
Jupiter 10	Lysithea	(15)	11,857,000	263 13 --	1938, Nicholson
Jupiter 12	Ananke	(15)	21,240,000	631 02 --R	1951, Nicholson
Jupiter 11	Carme	(15)	22,530,000	692 12 --R	1938, Nicholson
Jupiter 8	Pasiphae	(15)	23,500,000	738 22 --R	1908, Melotte
Jupiter 9	Sinope	(15)	23,700,000	758 -- --R	1914, Nicholson
Saturn 10	Janus	(350)	160,000	00 17 59	1966, Dollfus
Saturn 7	Mimas	(900)	187,000	00 22 37	1789, Herschel
Saturn 8	Enceladus	550	238,000	01 08 53	1789, Herschel
Saturn 5	Tethys	1,200	295,000	01 21 18	1684, Cassini
Saturn 6	Dione	800	378,000	02 17 41	1684, Cassini
Saturn 4	Rhea	1,300	526,000	04 12 25	1672, Cassini
Saturn 1	Titan	5,800*	1,221,000	15 22 41	1655, Huychens
Saturn 2	Hyperion	(320)	1,480,000	21 06 38	1848, Bond
Saturn 3	Iapetus	(1,150)	3,561,000	79 07 56	1671, Cassini
Saturn 9	Phoebe	(260)	12,960,000	550 11 --R	1898, Pickering
Uranus 5	Miranda	(550)	124,000	01 09 56	1948, Kuiper
Uranus 3	Ariel	(1,450)	191,000	02 12 29	1851, Lassell
Uranus 4	Umbriel	(970)	267,000	04 03 38	1851, Lassell
Uranus 1	Titania	(1,800)	438,000	08 16 56	1787, Herschel
Uranus 2	Oberon	(1,600)	587,000	13 11 07	1787, Herschel
Neptune 1	Triton	3,800	354,000	05 21 03R	1846, Lassell
Neptune 2	Nereid	(530)	5,570,000	359 10 --	1949, Kuiper
Pluto 1	1978 P1	Provisional Designation	20,000	06 09 17	1978, Christy

MERCURY and VENUS have no known satellites.

*-Recent Value ()=Uncertain Value R=Retrograde Orbit

Io, Europa, Ganymede and Callisto were discovered by Galileo with a crude telescope, and they can be seen in an ordinary pair of 6 or 7 power binoculars.

Charles Kowal at Cal. Tech. has detected an object that may be a 14th moon of Jupiter.

THE GREAT PLANETARY CONJUNCTION OF 1981

The Great conjunction of 1981 is unusual because Jupiter and Saturn appear to pass each other three times this year, between January and the end of July. The earth must be in exactly the right position in space for us to see a triple Jupiter/Saturn approach. The event is a rare one. The last similar triple conjunction occured in 1940-41, and the next will not happen for 258 years.

As the planets orbit the Sun, from our viewpoint on Earth, they occasionally appear to move very close together. When they appear closest together they are said to be in conjunction. Of course, the planets never really get close in space. At present Jupiter is 700 million kilometers from Earth. Saturn is in the same direction as Jupiter, as seen from the Earth, but it is nearly twice as far away at a distance of 1.3 billion kilometers.

As Jupiter and Saturn move around the sky, Jupiter overtakes Saturn and the planets come into conjunction about every 19 years. The planets seldom come so close together that they appear as one star. Usually they pass within a degree or two of each other. For reference, the Moon appears 1/2 degree in diameter.

This is the last conjunction of Jupiter and Saturn that will be visible until December 21, 2020. The conjunction of May 28, 2000, will be so close to the Sun that it will be invisible in the Sun's glare. The 1981 triple conjunction is the eleventh since 7 BC. The 7 BC conjunction, according to some scholars, set the Wise Men on their journey to Bethlehem, and provided the origin for the Planetarium's story of the Christmas Star.

The following is a timetable of events to watch for in 1981:

Wednesday, January 14	First Conjunction - Jupiter and Saturn 1.1 degrees apart. (The Moon is 1/2 degree across).
Sunday, January 25	Moon within 2 or 3 degrees of Jupiter and Saturn. This will be a very pretty sight between 11 p.m. and dawn.
Thursday, February 19	Second Conjunction. Jupiter and Saturn, after moving apart slightly are again close, only 1.1 degrees apart.
Saturday, February 21	Moon again close to Jupiter and Saturn.

THE GREAT PLANETARY CONJUNCTION OF 1981 cont'd.

Thursday, July 30	Third Conjunction. Jupiter 1.2 degrees from Saturn. In the winter and spring these planets were seen in the late night and morning sky. Now they are in the southwest early in the evening.
July 25 to July 28	Venus moves past Jupiter and Saturn coming within 2 degrees of Jupiter and 0.9 degrees of Saturn. These three planets will, by the end of July be very low in the southwest at sunset.

Between the first and second conjunctions, the separation between the planets increases only from 1.1 degrees to about 1 1/4 degrees. Since Jupiter and Saturn are moving near a faint star, Eta, in the constellation Virgo, it is easy to note even the minute day to day changes in their positions.

Between the second and third conjunctions the planets will separate until they are nearly 3 degrees apart in mid-May. Between August 24 and Sept. 1, Jupiter, Saturn, Venus, the Moon and the bright star Spica will form a series of configurations in the southwestern sky in the evening. These will be fascinating to watch as they change their positions day to day.

A pair of binoculars, if focused carefully and braced against a fence post or a door frame will give an interesting view of the Moon and Planets. (Do not look through a window as it will make the image fuzzy). Binoculars won't quite show the rings of Saturn, but they will show the craters on the Moon and four of Jupiter's Moons.

for further information:
Bill Peters or
Kathy Roos Pavlik
956-2830 ext. 127 or 147

MANITOBA PLANETARIUM

Astronomical Information

METEORS AND METEOR SHOWERS

The earth is constantly bombarded by large and small particles from outer space. Since the earth travels through space at a velocity of almost 108,000 kilometers per hour, it often collides with particles in space which are heated up as they enter the atmosphere. Most of the smaller pieces burn up before they reach the ground. Some of the larger ones that do reach the ground are recovered. These are called meteorites. Meteorites fall into three classes; stony (aerolites), irons (siderites) and stony-irons (siderolites). Stony meteors often break up at the end of their flight. Meteors whose trains are coloured are likely to be metallic in composition.

DEFINITIONS: The particle, when it is still in space, is called a meteroid; the luminous phenomen caused when the particle enters the earth's atmosphere is a meteor; and if it survives and lands on the ground, the particle is a meteorite. No known meteorite is of shoer origin.

SOME FACTS ABOUT METEORS

Velocity of Observed Meteors	144,000 km./hr	15-75 km/sec.
Average Rate of Visible meteors for a single observer (not during shower)	10 per hour	
Rate of a Shower	15 - 50 per hour	
Daily Mass of Material Reaching Earth	50 - 100 Metric Tons	
Meteor Surface Temperature at Maximum	300°K	
Height of Appearance of Meteors	Sporadic 100 km.	Shower 115 km.
Largest known Meteorite	9 cubic meters (found in South Africa)	

MANITOBA PLANETARIUM

Astronomical Information

COMETS

Comets are strange space wanderers, once regarded as from outer space, but now regarded as being part of our solar system. some of the stuff left over when the planets formed. This leftover material orbits the sun outside Pluto, and occasionally some condensations of it form and begin to travel in altered paths that bring them within our observation. As they approach the sun they begin to glow as the frozen material of the comet is turned to gas and excited by the sun's radiation.

Four names are given to observable parts of a comet. The head is called the coma and may show two characteristics; an indistinct central condensation and a much smaller bright fuzzy spot called the nucleus. Extending away from the coma is the characteristic tail of the comet. The tail is formed by gases and small particles driven out of the coma by the solar wind and radiation pressure of the sun. The tail may fork, the lighter gas molecules being driven in straight lines away from the sun by radiation, and heavier dust particles curving away affected both by solar wind and gravitation.

Periodic comets are those known to reappear at more or less regular intervals. All comets are now regarded as probably periodic unless perturbed so that they escape from the solar system.

SOME FACTS ABOUT COMETS

Average period of a periodic comet	Approx. 7 years (most of the bright ones are longer than this)
Average perihelion distance (closest approach to the sun)	153,000,000 km.
*Average magnitude	9.5
Rate of Discovery of Comets	
New Indefinite Period	3 per year
New Periodic	1 per year
Periodic (predicted and observed on a subsequent passage)	2.5 per year
Comets visible to the naked eye	2 per year
Average number of appearances before breaking up	7
*Diameter of coma	Approx. 274,000 km.
Diameter of central condensation	Approx. 2,700 km.
Diameter of nucleus	Approx. 13 km.
Length of tail visible to the eye	from 9,650,000 km. to 200,000,000 km. in special cases

Solar distance at which tail appears	Approx. 240,000,000 km.
Atoms & molecules observed in comet heads	Water, Sodium, Carbon, Cyanide, Methane, Ammonia
Atoms & molecules observed in comet tails	Cyanide, Nitrogen, Carbon Dioxide

*These characteristics change with solar distance and thus are given here for the perihelion distance.

MANITOBA PLANETARIUM

Astronomical Information Sheet

THE MILKY WAY

Our sun is located approximately two thirds of the way out from the centre of a huge aggregation of stars that is shaped like an enormous pinwheel. The pinwheel is slightly thicker at the centre than at its edge, and is called the Milky Way Galaxy. Distances in our Galaxy are so great that it is impractical to use our familiar yardsticks such as centimeter, meters and kilometers to measure them. The measurement that astronomers often use is called the light-year, and it is the distance that light can travel (at 300,000 km. per second) in the course of one year. However, for reasons of convenience, astronomers more often use the parsec to measure distances. The parsec is equal to 3.26 light years, and thus contains about 30,850,000,000,000 kilometers!

Astronomers find that our sun and the rest of the stars in the galaxy are moving with respect to each other as our galaxy rotates. Although this movement is quite rapid, the distances involved are so great that we could not notice the change in position of any of the stars until tens of thousands of years had passed!

We also know that the galaxy contains, besides individual stars, gas clouds (called nebulae) and special groups of stars called clusters. These are all rotating around the centre of the galaxy with all the rest of the stars.

SOME FACTS ABOUT THE GALAXY

Diameter	25,000 parsecs (pc.)
Thickness at the centre	4,000 pc.
Thickness at the sun's location	300 pc.
Distance between spiral arms	1,400 pc.
Thickness of spiral arms	600 pc.
Mass	1.1×10^{11} solar masses
Period of Rotation of the Sun around the Galaxy	200,000,000 years
Velocity of the sun's motion in the Galaxy	774,000 km. per hour

MANITOBA PLANETARIUM
Astronomical Information Sheet
QUASARS AND PULSARS

Quasars are possibly the most puzzling astronomical objects yet discovered. Although we have known about them since 1960, astronomers have not yet been able to explain them. They were first noted as being very small sources of powerful radio waves. Optical telescopes revealed them as objects that looked like stars. However, our spectroscopes show us that they are travelling away from us with enormous velocity, greater than that of any object in space that we have observed so far.

Astronomers believe that the very high velocity of quasars is due to the expansion of the universe. This would mean that they are the most distant objects ever observed, with distances up to 9 billion light years! However, they seem much too bright to be so far away. If they really were at that distance they would have to be as bright as one hundred thousand million of our suns! Astronomers are still not sure if it is even possible for an object to be that bright!

We also find that the light from these objects is variable. The laws of physics tell us that an object which varies as rapidly as quasars do, must be quite small. However, if they are as bright as mentioned above they certainly cannot be that small.

Unfortunately, we find that as our observations of these objects increase, we find no answers, only more questions. Some astronomers believe that quasars are early stages in the formation of a galaxy. Others feel that they might not even be all that far away, but then it is difficult to explain the high velocity.

It is very likely that the puzzle of the quasars will remain unsolved for quite a number of years.

Pulsars, on the other hand, were very quickly explained after being discovered. The first one was observed in 1967 by astronomers at Cambridge University using a radio telescope. They found that the pulsar emitted radio pulses about once every second. The remarkable feature of these pulses was their regularity. They would repeat with an accuracy of much less than one one-millionth of a second. For a short time it was believed that they might be signals from some intelligent civilization on another world. However, soon many more were discovered and this theory was discounted.

It was not long before pulsars were identified with faint stars that appeared to be quite unusual in nature. These were believed to be neutron stars; the final product of the cataclysmic explosion of a very old star. This explosion is called a supernova. The neutron star theory was proven to be correct when a pulsar was discovered in the Crab Nebula, the known remains of such an explosion.

These neutron stars are rotating extremely rapidly and have strong magnetic fields. The combination of these two characteristics gives rise to the rapid radio pulses.

Although astronomers have now solved the mystery of pulsars, they are still very much interested in them. They can tell us a great deal about the life cycle of stars, and their radio pulses can be used to perform other experiments in space to test theories like relativity, for example, or to study the nature of invisible material in outer space.

RESOURCES LIST

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MANITOBA PLANETARIUM

Astronomical Information Sheet

The Manitoba Planetarium is a multi-purpose audio visual theatre dedicated to providing the best in Astronomical and Entertainment programming for Manitobans and visitors. The Planetarium project was inspired by Canada's Centennial in 1967 and its construction was, in part, made possible through the generosity of the family of Saidye and Samuel Bronfman. Since the Manitoba Planetarium opened on May 15th, 1968 it has attained a significant place in the international Planetarium community. In addition, it has hosted light shows, religious services and artistic performances.

THE STAR THEATRE

The Planetarium's dome is the biggest projection screen in Manitoba. Literally hundreds of projectors work together to fill it with imagery. One hundred and fifty four separate projectors are clustered on the Zeiss Planetarium Projector in the centre of the room. These projectors work together to show nearly 9,000 stars - all that the unaided eye can see - as well as the Sun, Moon and Planets. The Zeiss Instrument gears these projectors together so accurately that they can be used to show the sky as our ancestors saw it thousands of years ago, or as Earthlings will see it far in the future.

When the Carl Zeiss Optical Company of Oberkochen, West Germany produced this projector in 1966 it sold for $200,000. The current cost of a similar projector is in excess of $1 million.

The Planetarium Design and Engineering staff has created the many special effects projectors that are hidden in the projection gallery, running all around the bottom edge of the dome. These projectors can produce an awe inspiring sunset, the landscape on distant world, the strange views seen by an interstellar traveller, or even a death defying plunge through a Black Hole. All of the projectors are run by a very busy operator from the control console in the Star Theatre.

PLANETARIUM SHOWS

Most Astronomical shows are written and produced right at the Manitoba Planetarium. Occasionally an outstanding production, created at another Planetarium, is presented in the star theatre. Scripting, artwork, and recording are done by the Planetarium's Director, Producers and Artist/Photographer. Narrators, actors, actresses and film-makers of local and national stature add their talents to the creation of the feature presentations.

Over a dozen exciting programs are presented every year for students from kindergarten through high school. These shows touch all aspects of astronomy, from the intriguing sky lore of the ancient Greeks to the mysterious Quasars at the edge of the visible Universe.

PLANETARIUM INFORMATION

To see a feature presentation call 943-3142 for show times and information. Information and bookings for our complete range of School Programs is available at 943-3204. Group visits and special events can be arranged by calling the Planetarium offices at 956-2830. When planning a visit be sure to leave time to tour the Hall of Astronomy, a 7,500 sq. foot exhibit gallery that takes a colourful look at star-gazing from ancient times through the revelations modern telescopes and spaceflight. In the gallery the Copernicus Solar Telescope projects an impressive, detailed, 52 inch diameter image of the Sun, every clear day.

THE SKY SHOW

For a brief, fun course in skywatching to really start appreciating the wonders of a dark evening sky, don't miss "The Sky Show'. This special performance is presented live on the second Sunday of each month at 5:00 pm. and it includes a free star map.

MANITOBA PLANETARIUM
and
MANITOBA CENTRE FOR U.F.O. STUDIES

UNIDENTIFIED FLYING OBJECTS

I. What is a U.F.O.?

An Unidentified Flying Object is exactly what it's name implies. It is something that seems to travel through the air or even to land, but we cannot explain what it is.

More than 90% of all the Unidentified Flying Objects that are reported, can ultimately be identified as natural or man made phenomena. However, even after careful analysis by skeptical investigators, a small number of reported sightings remain completely mysterious. Such a wide variety of observations fit in this unexplained category that one prominant investigator, Dr. J. Allen Hynek has sorted them into three main groups for convenience:

1. Close Encounters of the First Kind: In which the reported UFO is seen at close range but there is no interaction with the environment.

2. Close Encounters of the Second Kind: Are those where physical effects on both animate and inanimate material are noted, i.e., vegetation has been pressed down, burned or scorched, tree branches broken, animals frightened. Vehicles have become momentarily disabled. After the close encounter of the second kind left, the vehicles were usually able to operate again.

3. Close Encounters of the Third Kind: In which the presence of "Occupants" are reported in or about the UFO. There should be a distinction made between this type of report and the so-called contactee cases. The latter are characterised by a "favoured" human intermediary who believes he/she has been "chosen" by the space people as their regular contact to spread the messages they give to the contactee. These messages usually deal with such things as "be good, stop fighting, stop polluting the atmosphere and ban the bomb" etc. This later type of reporting is not classified as close encounters of the third kind.

Reference: Dr. J. Allen Hynek - "The UFO Experience" pgs. 28-31 inclusive.

In addition to the close encounter catagories there are two broad groups.

Nocturnal Lights: Unidentified lights, seen at night, which usually only the relative brightness, color and motion are reported.

Daylight Disks: Unidentified objects, usually oval or disk-shaped seen during the day.

What do these close encounters and unexplained sightings mean?

There simply isn't enough conclusive evidence to give a good answer to that question but many people have theories or beliefs about what the answer should be.

II. The Problem of Objectivity?

Scientists usually attack an unexplained phenomena by thinking up a hypothesis that seems to explain what is going on. Then they do some experiments or make some observations which are critical tests of the hypothesis to determine whether it is true or false.

Very often in science, until the correct theory comes along or until a good set of tests are invented, several hypotheses will exist side by side to explain some phenomena. This is exactly what seems to be happening in the case of Unidentified Flying Objects. There are several hypotheses but so far the process of supplying critical tests hasn't really begun.

Unfortunately, some "investigators" of unidentified flying objects have already made up their minds about the phenomena. Rather than seeking the critical tests for their theory, they pick out bits and pieces of evidence that seem to prop up their ideas and they use these bits and pieces to sell their beliefs in sensational articles and books. Some of these "investigator's" tales might make gripping or even scary reading, but they do little to solve the problems of what U.F.O.'s are. We recommend that all books and articles be read with a very critical mind. The mere fact that a statement or even a picture exists on a printed page does not guarantee that it is true. A good author will always state the sources of his information. But even if this seems to be done you still have to ask "do his sources seem to be reliable?" "Am I hearing all sides of the story or only the facts that fit this theory?" Uncritical beliefs may ease the mind by erasing the doubts and questions but they do absolutely nothing to increase our knowledge about U.F.O.'s.

III. The Evidence Problem

In August 1972 a meteor so bright that it could be seen in full daylight, went streaking across the skys of North America. It appeared suddenly, was visible for scant minutes, and then disappeared. Yet the eye witness reports of this phenomena and the photographs by amateur photographers were so complete that Astronomers who studied the reports could learn almost everything they wanted to know about the object.

Astronomer and exobiologist Carl Sagan has pointed out that U.F.O.s are seen frequently by large groups of people, yet none have been as well photographed and as well reported as this single rare meteor was. Why not? There's no easy answer to that question.

Psychological suggestion deserves more study than it has received thus far. Any stage hypnotist can easily demonstrate the power that an authoritarian figure exercises over a susceptible subject, even to the extent of altering the subjects perception. It could be that preconceived or even subconscious notions of what U.F.O.'s are, effects our reports. Even ignoring the less obvious psychological problems, there's another problem with U.F.O. evidence.

Since the photographs are poor, most of the evidence consists of eye witness reports. Unfortunately, eye witness reports tend to be highly unreliable. And this is true of eye witness reports of just about everything, not only U.F.O.'s. A law professor once demonstrated this to his class by arranging a "crime" to take place in front of them. When the class convened, one of the students got up, "shot" the professor with a blank cartridge and fled from the room. After allowing the confusion to continue for a minute or two the professor revealed that he was unhurt. That day's assignment was to write an exact account of what each student had seen. At the end of class the professor collected as many different accounts of the event as there were students in the room, and the differences weren't minor either. In the confusion, some of the observers had even managed to switch, in their minds, the victim and the assailant.

IV. Recording and Reporting a U.F.O.

If you see a U.F.O. it is important to get as many other witnesses as possible. If you have a camera handy be sure to take lots and lots of pictures. Along with your observation of the object, U.F.O. investigators will want to know the date, the time, the weather conditions, the shape of the object, its color, its behaviour and motion, and its size compared to the size of objects that you can see around you while observing it, and its apparent speed. They will also be interested in the duration of the appearance and how the object disappeared.

If there are a number of witnesses record their names, addresses and telephone numbers. As soon as you can, try and make a drawing of the object to keep the event fresh in your mind. Once you are satisfield that the U.F.O. is really unidentified and not just an unusual look at something familiar like an airplane, the planet Venus, a weather balloon, a flight of birds over the city illuminated by street lights at night, then call the Manitoba Planetarium at 190 Rupert Avenue, Winnipeg, Manitoba, Canada, R3B ON2, area code 204-956-2830 during business hours and ask to talk to a representative of the Manitoba Centre for U.F.O. Studies. Reports are accepted in confidence and no details relating personally to the witnesses or associated parties will be made public, without written authorization from the individuals concerned. Remember, to be of use, reports must be complete. All of the information listed above is needed to make further study possible.

Over 90% of the things that people report as U.F.O.'s can be explained. This is partly due to the fact that many are simply unfamiliar with the ways the moon and planets and other celestial objects appear overhead. A visit to the planetarium to enjoy the wonders and the splendors of the sky will help to make you a better observer of U.F.O.'s.

V. Extraterrestrial Life

The most persuasive explanation for U.F.O.'s is that they are piloted or controlled by intelligences who inhabit some other place in the Universe besides the planet Earth. Present scientific knowledge does not exclude this possibility. Terrance Dickinson, reporting to the 1977 General Assembly of the Royal Astronomical Society of Canada has concluded that in our galaxy, The Milky Way, there are possibly four hundred earth like civilizations. That's an optimistic estimate, he also concludes that it's distinctly possible that we are alone. Dickinson's arguments are entirely statistical ones. The planets in our own solar system are the only planets that we have solid evidence for. Scientists have indirect evidence that there are planets about many other stars, but even the largest telescopes won't give us a look at any of these.

When we contemplate the idea of travelling to other stars, the problems seem very great. Travelling as close as we could to that Universal speed limit, the speed of light, it would take many years to reach even the nearest star, Alpha Centauri which is 4 1/3 light years away. Science Fiction writers have invented hyper-drives to the speed of light but these ideas remain science fiction. It may or may not be possible to exceed this cosmic speed limit. At the moment we simply don't know.

One thing is certain. If U.F.O.'s are space ships from elsewhere those controlling them have found ways to do things we find exceedingly difficult. This may be the case. However, its equally likely that some day those who believe that U.F.O.'s are interstellar visitors will be disappointed when it's established that U.F.O.'s are actually something far different, perhaps even something psychological rather than something physical.

Further reading:

HYNEK, Allen J.

The UFO Experience

The Hynek UFO Report

The Edge of Reality

VALLEE, Jacque

Challenge to Science, The UFO Enigma

Pass-Port to Magonia

Invisible College

FULLER, John G.

Incident At Exeter

Interrupted Journey

JACOBS, David Michael

The UFO Controversy in America

LORENSEN, Coral & Jim

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February 1981

ASTRONOMY

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16 MM FILMS FROM SCHOOL FILM SERVICES

ABOUT ASTRONAUTS (11 min., color). Film footage from the Apollo lunar flights provides the visual base for the answers to the questions of a child's letter to NASA: Is being an astronaut really dangerous? The moon is not as big as the earth -- doesn't that mean people weigh less up there? How long is it before you come back to earth? Is moonwalking really that different from earthwalking? It takes a lot of people to launch a spaceship -- are all those people necessary? Is it true that scientists can learn more about the earth and the whole universe by studying the moon?
(1973) Primary to Jr. High.

AMAZING ADVENTURES OF GEMINI IV (10 min., b & w). (1965) Primary to Sr. High.

COMETS, METEORITES AND ASTEROIDS (11 min., color). Comets, Meteorites and Asteroids are called the minor members of the solar system. This film shows: 1) how astronomers have learned about these objects travelling around the sun; 2) what each group looks like; and 3) the place of each in the solar system. The film illustrates the newest objects in the solar system: Man-made or artificial, satellites.
(1962) Jr. High to Sr. High.

CONTROVERSY OVER THE MOON (16 min., color). The film presents the "controversy" concerning the geological make-up of the moon -- specifically the origin of large lunar craters. Two eminent scientists interpret available data and discuss reasons for their divergent views.
(1971) Intermediate to Sr. High.

EARTH, SUN, MOON & STARS - POSITION OF THE MOON (8 min., color). Actual pictures of the moon as well as space planetarium views show the moon as earth's nearest neighbour in space, explaining fully the major movements of the moon, its revolving and rotating, and the causes of moonlight. Demonstrations show the comparative sizes of the earth, sun and moon, and their relative distance from one another.
(1971) Intermediate to Jr. High.

ECLIPSE AT GRAND'MERE (10 min., b & w). The eclipse of the sun on July 10, 1963, drew scientists and amateur stargazers from far afield to the little out-of-the-way town of Grand'Mere, Quebec, a place where the total eclipse was to be plainly visible. This film presents candid camera views of the festivities with which the modest town greeted the influx of visitors, and also shows the once-in-a-lifetime spectacle of the moon inching across the face of the sun, to blot it out completely.
(1965) Jr. High to Sr. High.

ECLIPSES OF THE SUN AND MOON (11 min.). Stop-motion and time-lapse photography are used to bring an actual solar eclipse to the screen. An animation sequence reveals the cause and effect of a total solar eclipse.
(1966) Jr. High to Sr. High - Adult.

EDGE OF THE UNIVERSE, TO THE (22 min., color). An account of the construction, in Algonquin Park, Ontario, of a radiotelescope designed by Canada's National Research Council, and how it was used to measure, working simultaneously with the telescope of the Dominion Radio Astrophysical Observatory at Penticton, B.C., the first arc of a "quasar" (quasi-stellar radio source) at the outermost fringe of our universe. The success of this probe opened up new possibilities of astronomical enquiry.
(1973) Sr. High.

EXPLORING THE MOON (20 min., color). (1960) Intermediate to Sr. High.

FIRST MEN INTO SPACE (20 min., color). Solving the space survival problems. Recreates, with live photography, film animation, and scale models, the first American orbital space flight, and illustrates some of the problems of man's survival in this hostile environment. Shows how such problems as decreased air pressure, multi-weight, and weightlessness were studied and how solutions were applied by engineers to the first space capsule project.
(1962) Intermediate to Sr. High.

HOW WE EXPLORE SPACE (16 min., color). An introduction to the instruments astronomers use and the methods used to explore space and to study planets and stars. The instruments shown are the telescope, camera, spectroscope and photo-cell. The various planets are examined by these instruments. Also, included, are some of the first color pictures taken of Mars.
(1958) Jr. High to Sr. High.

HOW WE KNOW THE EARTH'S SHAPE (11 min., color). We use a globe as a model to represent the shape of the earth. But how do we know what the earth's shape really is? The film shows how, during the centuries, man has changed his ideas about what the earth looks like: from flat, to curved, to round, to flattened and bulging, to pear-shaped. Yet, a perfectly round globe is still the best model of the shape of the earth.
(1960) Elementary to Jr. High.

MILKY WAY AND BEYOND (20 min., color). Presents the relationship of our solar system to the galaxy of which it is a part. Telescopic color photography and effective animation illustrate what stars are and how they are formed. An expanding picture of the universe is gained as other galaxies and their movements are portrayed.
(1961) Intermediate to Sr. High.

MOON, THE (15 min., color). (1963) Primary to Intermediate.

OTHER PLANETS - NO PLACE LIKE EARTH (30 min., color). What are the similarities and differences between Earth and the other planets of the solar system? Computer animation is used to summarize the knowledge scientists have gained to date.
(1971) Intermediate to Sr. High.

RED PLANET, MARS (17 min., color). Animation and still photographs are used to show Mars in the solar system. Historical observations are cited. With diagrams for the space satellites, indication is given of how man may one day be able to get a closer view of the surface of the planet. Some details of the satellite Mariner indicate how close-ups of the planet will be secured and sent back to the earth.
(1971) Intermediate to Sr. High.

SATELLITES - STEPPING STONES TO SPACE (20 min., color). (1959) Intermediate to Sr. High.

SOLAR FAMILY, THE (10 min., b & w). Makes an introductory study of the planets - their evolution, motions, sizes and satellites. Describes with animated drawings the evolution of the solar system according to planetesimal hypothesis, and traces the real and apparent motions of the planets. Reveals special phenomena pertaining to certain planets, and describes the planetoids, Halley's comet, and the movement of the solar system.
(1936) Jr. High to Sr. High.

SOLAR SYSTEM (18 min., 2nd Ed.). This unusual animated film combines 3-dimensional models with "you-are-there" camera techniques to create an awesome sense of drifting through outer space.
(1978) Primary, Intermediate, Jr. High, Sr. High.

SUN AND HOW IT AFFECTS US (10 min., color). A comprehensive study of the sun is presented, including the sun's size, distance from the earth, physical nature, and it's effect on life, weather, and tides on earth. A basic understanding of the probable origin and effects of the corona, prominences, flares, and sun-spots is provided through telescopic motion pictures.
(1958) Intermediate to Jr. High.

SUN AND THE SOLAR SYSTEM (20 min., color). Discusses asteroids, meteors, the sun and the nine planets in the solar system. Explains why a planet travels around the sun.
(1963) Primary to Intermediate.

SUN'S FAMILY (10 min., b & w). Explains the nature of the solar system, discussing the sun and the planets that travel about it.
(1950) Intermediate to Jr. High.

TRIP TO THE MOON (16 min., color). An imaginary rocket takes off to the moon and explores its surface. During the trip we learn many facts about conditions met in navigation to the moon. Once above the moon's surface, the film shows in detail the craters and "seas", the valleys and mountains that can be seen from the earth. The film combines animation and model photography to create a realistic illusion of a study of the moon's surface.
(1957) Intermediate to Sr. High.

UNDERSTANDING OUR UNIVERSE (11 min., color). How man has learned about the universe from ancient times until the present day is demonstrated by this film which discusses our knowledge of the universe - the solar system, Milky Way and countless other galaxies and nebulae that extend millions of light years into space.
(1957) Intermediate to Sr. High.

UNIVERSE (26 min., b & w). A triumph of film art, creating on the screen a vast, awe-inspiring picture of the universe as it would appear to the voyager through space. Realistic animation takes you out beyond our solar system, into far regions of space perceived by the modern astronomer. Beyond the reach of the strongest telescope, past moon, sun, Milky Way, into galaxies yet unfathomed, you travel on into the staggering depths of the night, astonished, spellbound at the sheer immensity of the universe. Starting point for this journey is the David Dunlop Observatory, Toronto.
(1960) Jr. High to Sr. High.

UNIVERSE (28 min.). A motion picture that explores almost inconceivable extremes of size and time - from the vast islands of stars called galaxies, to sub-atomic particles; from cosmic events that occurred billions of years ago to microcosmic events in the present that endure for only a billionth of a second.
(1978) Sr. High, College, General.

THE UNIVERSE: BEYOND THE SOLAR SYSTEM (18 min.). This film takes viewers on an exciting visual journey, beginning with our solar system and extending into and through the farthest reaches of outer space.
(1978) Sr. High.

CONSTELLATIONS

Listed below are the 88 generally recognized constellations.

Visible Above 50° North

1. Andromeda	16. Cetus	31. Lacerta	46. Puppis
2. Antlia	17. Columba	32. Leo	47. Pyxis
3. Aquarius	18. Coma Berenices	33. Leo Minor	48. Sagitta
4. Aquila	19. Corona Borealis	34. Lepus	49. Sagittarius
5. Aries	20. Corvus	35. Libra	50. Scorpius
6. Auriga	21. Crater	36. Lynx	51. Sculptor
7. Bootes	22. Cygnus	37. Lyra	52. Scutum
8. Camelopardalis	23. Delphinus	38. Microscopium	53. Serpens
9. Cancer	24. Draco	39. Monoceros	54. Sextans
10. Canes Venatici	25. Equuleus	40. Ophiuchus	55. Taurus
11. Canis Major	26. Erdanus	41. Orion	56. Triangulum
12. Canis Minor	27. Fornax	42. Pegasus	57. Ursa Major
13. Capricornus	28. Gemini	43. Perseus	58. Ursa Minor
14. Cassiopeia	29. Hercules	44. Pisces	59. Virgo
15. Cepheus	30. Hydra	45. Piscis Austrinus	60. Vulpecula

Not Visible Above 50° North

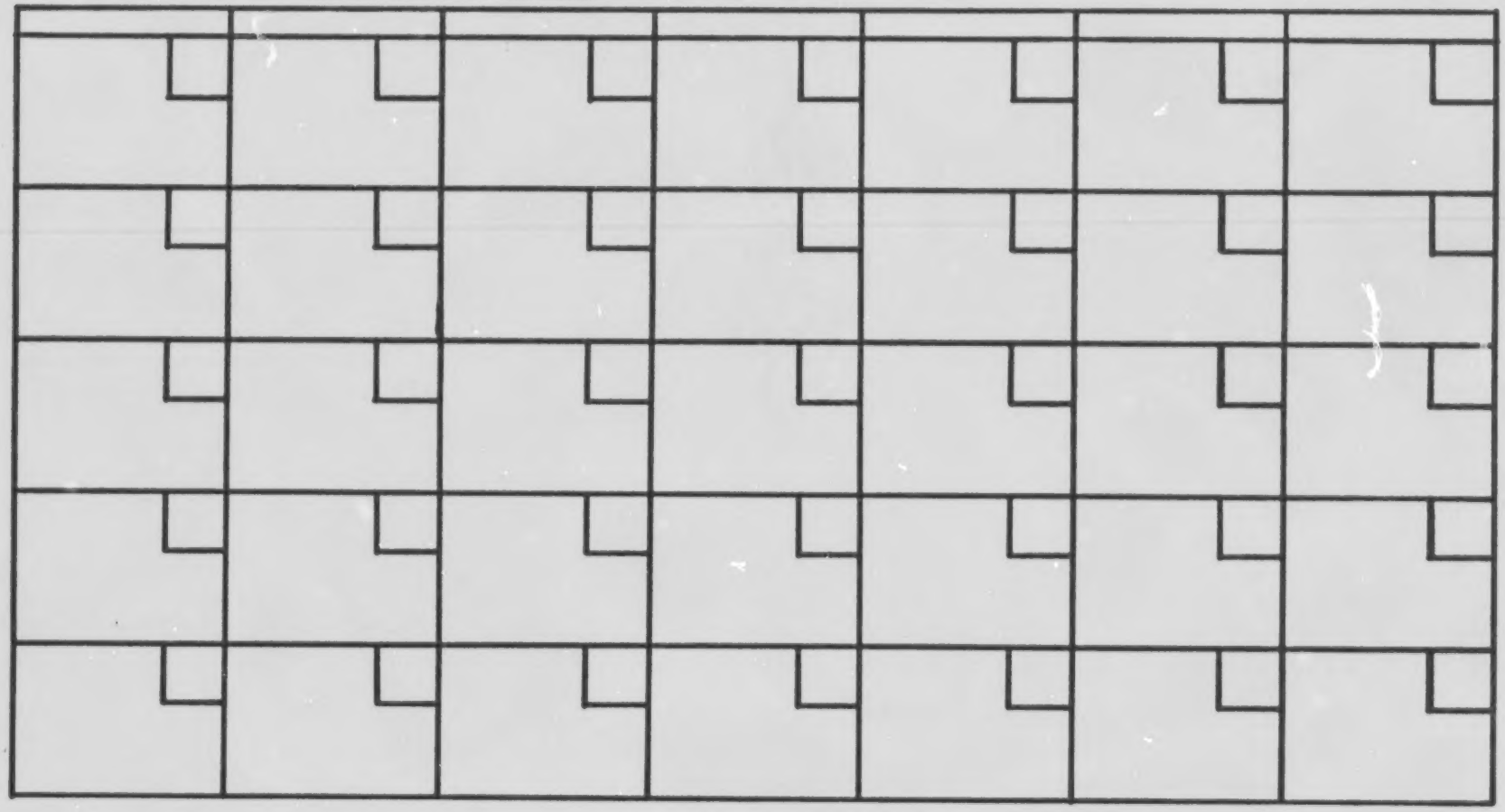
1. Apus	8. Corona Australis	15. Lupus	22. Pictor
2. Ara	9. Crux	16. Mensa	23. Reticulum
3. Caelum	10. Dorado	17. Musca	24. Telescopium
4. Carina	11. Grus	18. Norma	25. Triangulum Australe
5. Centaurus	12. Horologium	19. Octans	26. Tucana
6. Chamaeleon	13. Hydrus	20. Pavo	27. Vela
7. Circinus	14. Indus	21. Phoenix	28. Volans

21 BRIGHTEST STARS

Star	Constellation
Sirius	Canis Major
*Canopus	Carina
*Alpha Centauri	Centaurus
Arcturus	Bootes
Vega	Lyra
Capella	Auriga
Rigel	Orion
Procyon	Canis Minor
Achernar	Eridanus
*Beta Centauri	Centaurus
Betelgeuse	Orion
Altair	Aquila
Altair	Taurus
*Acrux	Crux
Spica	Virgo
Antares	Scorpio
Pollux	Gemini
Fomalhaut	Piscis Austrini
Deneb	Cygnus
*Becrux	Crux
Regulus	Leo

* not visible above 50° N.

MONTH _____



SUMMARY:

Constellation Slides

To make constellation slides you need the following:

-glue

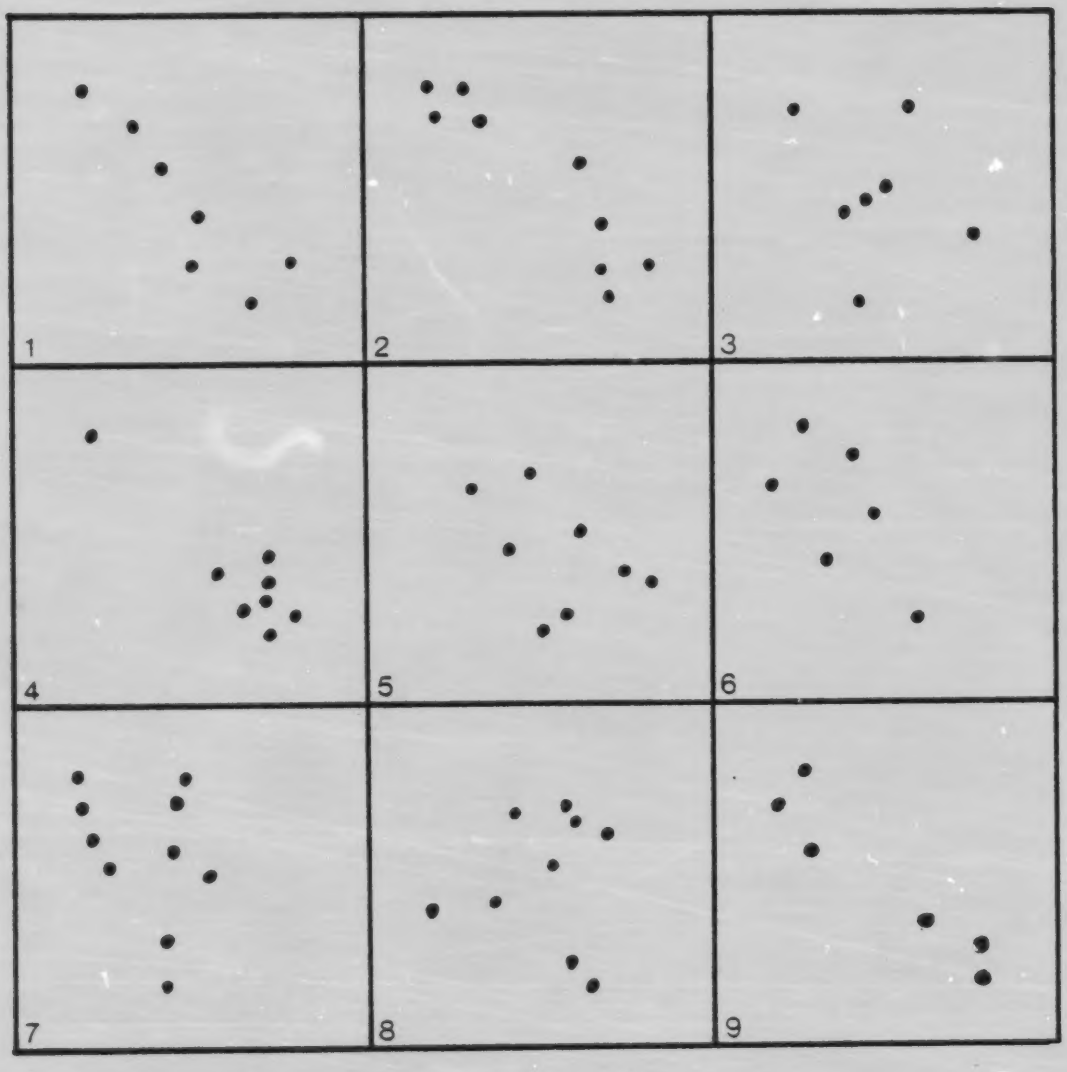
-construction paper

-scissors

-pointed object

35mm slide projector

1. Spread a thin coat of glue on the back of this sheet and affix it to a sheet of construction paper.
2. Label the constellations found in each box.
3. Separate the boxes.
4. Punch tiny holes (large enough to let light through) where stars are located.
5. Project these constellation slides in a 35mm slide projector.



ACTIVITIES

1. Challenge your friends to name the constellations correctly.
2. With a star map and using thin cardboard, make additional slides.

Constellation Cans

To make a simple constellation can you need the following:

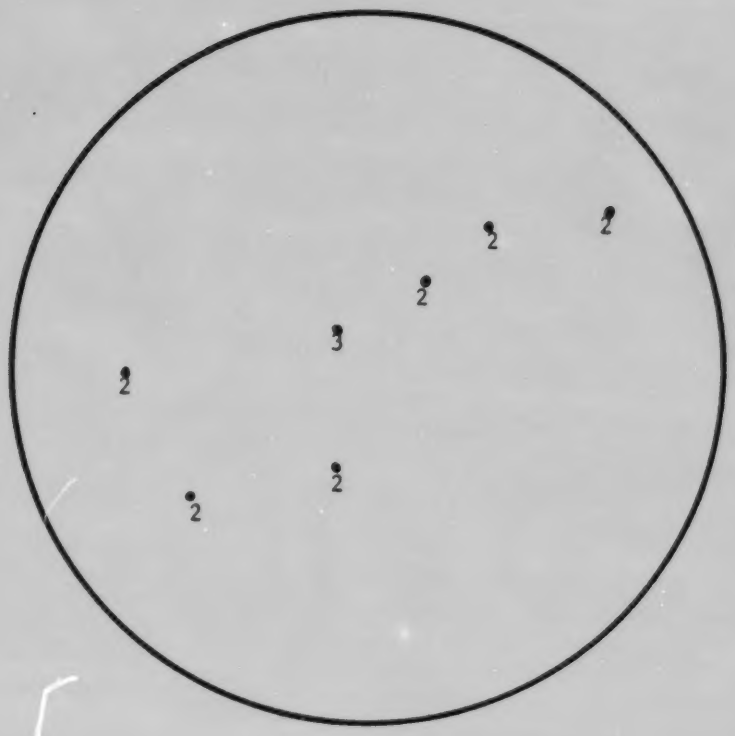
- large tin can from juice (48 oz.)
- hammer
- nails of different thicknesses (about 5)
- flashlight
- constellation discs (found on the following pages)
- scissors

Cut out a constellation disc and place it on the bottom of the can. Punch holes in the can at the positions marked for the stars. For larger stars use larger nails and for smaller stars use smaller nails to indicate the relative brightnesses of the stars.

Place the flashlight inside the can. When the room is darkened the image of the "stars" can be projected on the wall or ceiling.

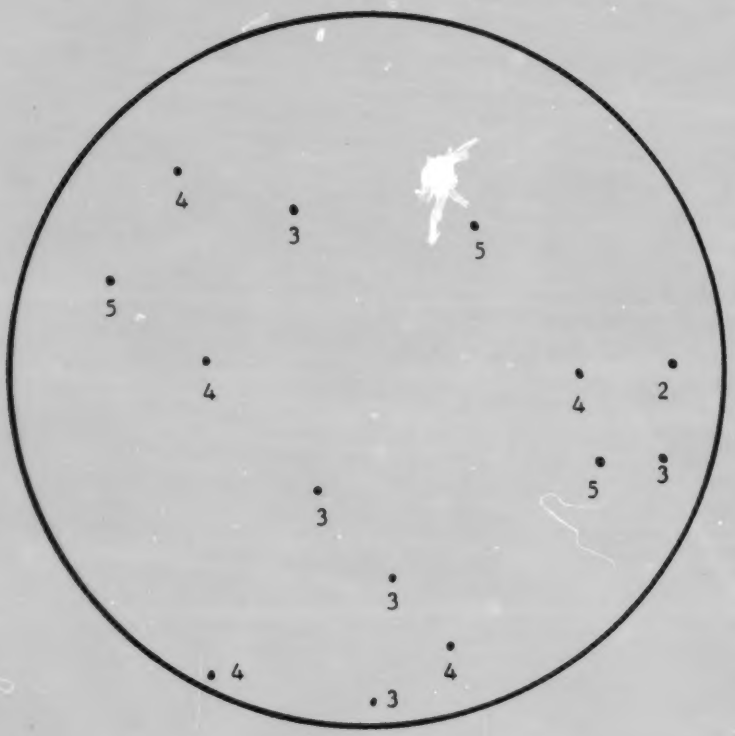
Students can project a large number of different constellations at one time on the wall and with the aid of a star chart they can simulate the sky with the constellations in the proper places in the sky.

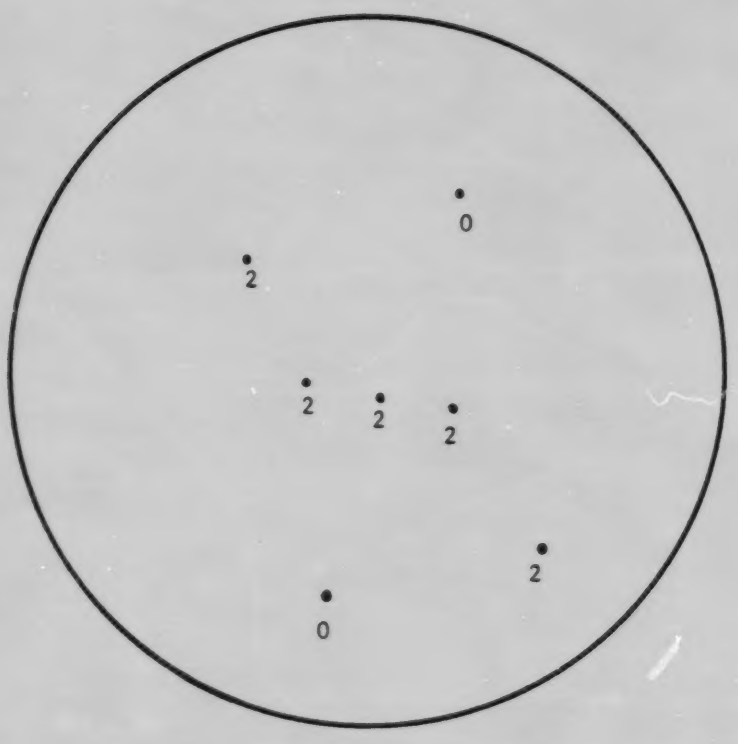
URSA MAJOR



URSA MINOR

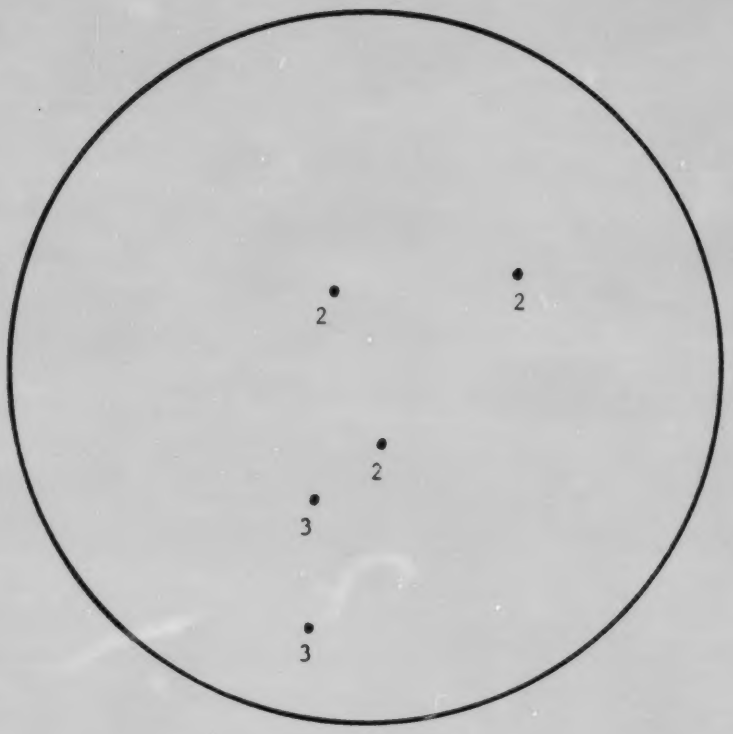
DRACO





ORION

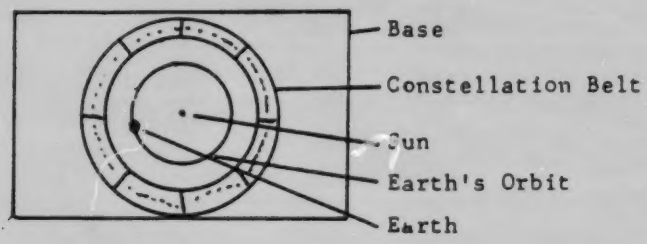
CASSIOPEIA



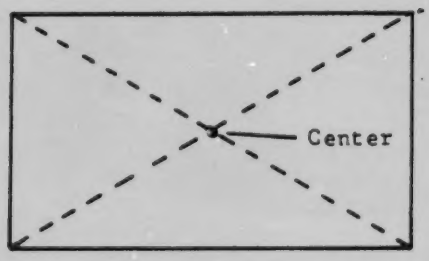
CEPHEUS

CONSTELLATION POSITIONS

This is to construct a three-dimensional model showing the constellations that can be seen along the Earth's orbit. These are known as the constellations of the zodiac.

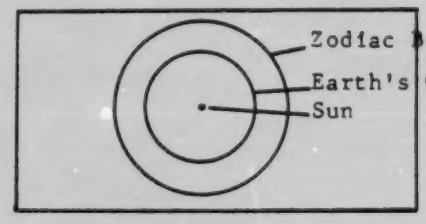


1. Find the middle of your poster paper by drawing lines from opposite corners.



2. Draw the elliptical orbit of the Earth around the Sun using two pins and a loop of string. One pin will be at the centre of the Sun, the other will be 2.5 cm from the Sun towards the bottom of the poster paper. Your loop of string should be 15 cm long.

3. Select a suitable radius for your zodiac belt as it goes around the Sun. Draw a large circle using a string, a pin and the Sun as the center of the circle.

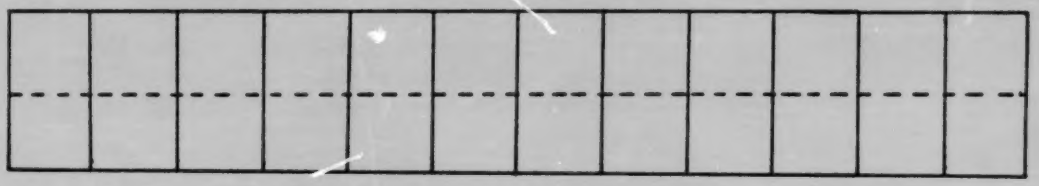


4. Now you must calculate the length of a paper strip that must go around the circumference of your circle. It is given by the formula:

circumference = 2 r where = 3.14
r = your radius

5. Cut your length of paper the right length and about 10 cm wide. Draw a line down the centre and label it the ECLIPTIC.

6. Divide your strip into 12 equal parts using pencil lines.

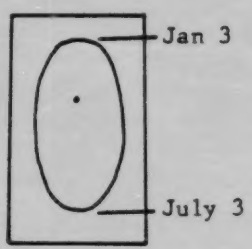


7. Starting from the right end of your strip you can begin to label the dates of the different zodiac constellations (obtain this from your local newspaper).

8. The constellations lie either slightly above or slightly below the ecliptic. This can be measured in degrees.

1. Aries	- 7-10° above	7. Libra	- 8° above to 8° below
2. Taurus	- 5° above to 5° below	8. Scorpius	- 0° to 20° below
3. Gemini	- top is 10° below	9. Sagitarrius	- 2° above to 12° below
4. Cancer	- on the line	10. Capricorn	- 10° above to 7° below
5. Leo	- top is 10° above	11. Aquarius	- 0° to 11° below
6. Virgo	- between 15° and 0° above	12. Pisces	- 0° to 10° below

9. Turn the strip into a loop and attach it to your poster paper. Remember the Earth is furthest from the Sun on July 4th and closest to the Sun on January 3rd.



This project will teach:

(1) the zodiac
(2) the ecliptic
(3) the elliptical orbits
(4) geometry

along with astronomy.

THE ROTATION AND REVOLUTION OF THE EARTH

The Rotation

The object of this observation is to measure the length of time required for the stars to appear to have revolved once about the Earth in order to determine the actual length of time required for the Earth to rotate once on its axis.

It is not necessary to watch the stars make a complete apparent revolution; watch them for an hour or so, and then compute how long would be required for them to turn once completely.

At the bottom of a page of 8½ x 11 paper draw a horizontal line to represent the northern horizon. Mark the center point of the line N; place NW at the left end, NE at the right. Up from the N draw a vertical at least 15 cm long. Mark the top Z. This line represents the northern half of the meridan, from the horizon to the zenith. Mark the position of Polaris about 5/9 of the way up from N. (Why 5/9?)

Early in the evening stand facing due north, at a place which can later be identified and reoccupied. Along the apparent horizon put any trees, lights, or other landmarks which show, to serve as reference points. Then draw in the sky, indicating by dots properly placed, the stars of the Big Dipper, the stars of the Little Dipper and the "W" of Cassiopeia. Record the date and time of completion of the sketch.

As late as possible, on the same evening, repeat this observation and sketch, on a second page ruled like the first, and again record the date and time.

The computation is a simple one, but first the two drawings must be measured. Using a protractor, measure the angle from the upper part of the meridan to a line drawn joining Polaris with each star of the first chart. Read this angle in a counterclockwise direction. Record the individual values of this angle in the second column of Table 1. Repeat for the second chart, recording the values in the third columnof the same table.

Subtract each of the values in column2 from the corresponding values in column 3, recording the differences in column 4. These are the angles through which the stars appeared to have moved, due to the rotation of the Earth. Add the values in column 4 and divide by 14 to obtain the mean. The values and mean may be carried to the nearest tenth of a degree. Divide this mean into 360°, and the result is the factor by which the time interval elapsing between the two observations, in minutes, is to be multipied, to give the rotation period of the Earth, in minutes. Divide by 60, to obtain the Earth's rotation period in hours, with a remainder of minutes.

The Revolution

On a third observation sheet, reled as before, repeat the observations at the same hour of the night for the first sketch, but on a night at least a month later.

Measure the sketch as before, and record the values in column 3 of Table 2. Column 2 should be filled in with the v lues of the corresponding column in Table 1.

Again take the differences, and the mean, and divide into 360°. This factor is now used to multiply the number of days elapsed from the first observation to the one just made. The result is the period of revolution of the Earth, in days.

1. Star	2	3	4
α Ursa Major			
β Ursa Major			
γ Ursa Major			
δ Ursa Major			
ε Ursa Major			
ζ Ursa Major			
η Ursa Major			
β Ursa Minor			
γ Ursa Minor			
β Cassiopeia			
α Cassiopeia			
γ Cassiopeia			
δ Cassiopeia			
ε Cassiopeia			

2. Star	2	3	4
α Ursa Major			
β Ursa Major			
γ Ursa Major			
δ Ursa Major			
ε Ursa Major			
ζ Ursa Major			
η Ursa Major			
β Ursa Minor			
γ Ursa Minor			
β Cassiopeia			
α Cassiopeia			
γ Cassiopeia			
δ Cassiopeia			
ε Cassiopeia			

ASTRONOMY PROJECT FOR SCHOOLS: PLANETS AND THE ZODIAC

Introduction

This project is designed to stimulate students' awareness of the celestial motions that aroused the curiosity of the first astronomers, thousands of years ago, and at the same time to view these motions in the more modern framework of our Solar System.

The actual observations must of course be done after dark, either individually or as a group, although observations in the planetarium might be used. In the classroom, a map of the Zodiac constellations will be drawn, and a Solar System Chart constructed, onto which the planets will be located, according to their locations in the sky. The planet locations can be up-dated from time to time by new observations.

Only normal classroom materials are required for this project, but star maps will be useful, since some of the fainter constellations are difficult to find, especially when observations are hampered by city lights.

Concepts

A visit to the Planetarium might be valuable to introduce some of the concepts involved in the project. The concepts that may be encountered, depending on the grade doing the project, are:

1. Identification of constellations, stars and planets.
2. The heavens as a sphere, with Earth at the centre; horizon circle and zenith point.
3. Motion of Moon; the zodiac circle; phases of Moon and calendars.
4. "Apparent" motion of Sun $\longrightarrow$ orbit of Earth; why we see different constellations at different seasons.
5. Positions of planets in their orbits determined by "apparent" positions against background stars.
6. Venus: morning or evening star; configurations of planets: conjunction, oppositions etc.
7. Periods of planets' revolution around Sun; Kepler's Laws.

Nightime (or Planetarium) Observations

Students can begin by learning to identify bright stars, constellations, and planets, and sketching these as they appear in the sky. The horizon, direction (N, S, E or W) and zenith point serve as references for orienting these sketches. If in doubt about the location of planets, consult an ephemeris, almanac, or call the Planetarium. With a little practice it is easy to find the planets Venus, Mars, Jupiter and Saturn. The fifth "naked-eye" planet, Mercury is usually hidden in the Sun's glare.

When the Moon is in the sky, students can sketch its phase, and attempt to determine in which constellation it is found. Originally, the Moon's path defined the Zodiac, and the Moon's phases defined the month.

In the Classroom

The Solar System Chart is constructed by drawing concentric circles to represent the planet orbits to scale around the Sun, at the center. If the Earth's orbit is one inch in radius, the others are Mercury 0.4"; Venus 0.7"; Mars 1.5"; Jupiter 5.2"; Saturn 9.5". The chart can be scaled up from these dimensions to as large as is desired.

The Zodiac constellations form a ring around the Solar System. They could simply be drawn in a ring around the outside of the Solar System Chart, but it is more effective to draw them on a strip of cardboard about 6" wide, and 6 ft. long, so that each Zodiac constellation occupies a 6" by 6" space. The ends of the cardboard are then joined to form a continuous ring, which is really part of the whole celestial sphere. In any case, it should be pointed out that the stars in this model are not to scale; they should be much further away. For instance, Pollux, one of the twin stars in Gemini and relatively nearby, should really be forty miles away on the scale of the Solar System used above.

Locating the Planets on the Chart

The Earth should be located first. Ideally, this would be done by observing which constellation the Sun is in, but obviously this is impossible. Instead the Earth's orbit can be divided into 12, going counter-clockwise. Seen from the Earth, the Sun is roughly in line with the following constellations for each month:

January - Sagittarius	July - Gemini
February - Capricornus	August - Cancer
March - Aquarius	September - Leo
April - Pisces	October - Virgo
May - Aries	November - Libra
June - Taurus	December - Scorpius

To check this, the students can see which constellation is due South (on the Meridian) at midnight. (The Sun is directly opposite, below the horizon in the north.) Two hours earlier, at 10 P.M., one constellation to the East will then be due South, on the Meridian, and so on.

Example: On Feb. 15, Taurus is on the Meridian at 8 P.M., Gemini at 10, and Cancer at midnight. Therefore the Sun is opposite Cancer, in Capricornus. It is apparent why Capricornus is not seen at this time of year.

The Earth's position can be labelled with the date. Then the other planets can be located on their obits by lining them up with the appropriate constellation, as seen from Earth. Each position should be labelled with the date, and may be marked with a coloured map pin, or model of that planet.

When the observations are repeated a month or so later, it will be seen that all the planets have shifted counter-clockwise round the Sun, with the outer planets moving more slowly than the inner ones, in accordance with Kepler's Laws. If the project is done carefully over a period of a few months, the periods of the planets' orbits may be determined.

The observations might be supplemented by using binoculars or a small telescope to examine the planets, and to look for other celestial objects. There is no end to the information about particular stars and constellations, that can be provided after the students have become familiar with these.

COSMIC CALENDAR

(adapted from The Dragons of Eden by Carl Sagan)

To express a cosmic chronology is to imagine the 15 billion years lifetime of the universe compressed into the span of a single year. If one were to do so the calendar would look something like this:

January - November

January 1	The Big Bang
September 9	Origin of the Solar System
September 14	Formation of the Earth
September 25	Origin of life on the Earth
October 9	Date of oldest fossils

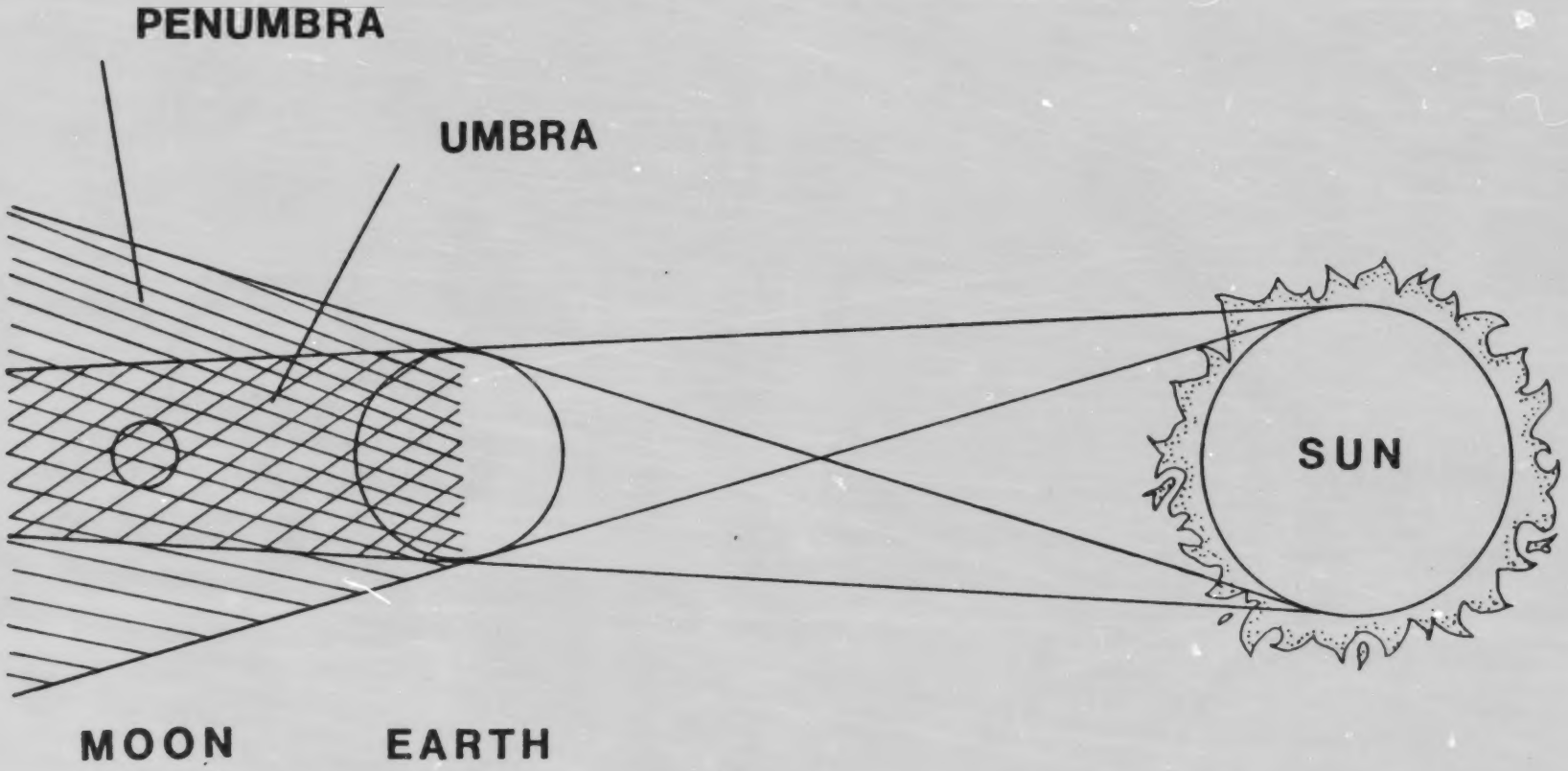
December

December 1	Significant oxygen atmosphere begins to develop on Earth
December 5	Extensive vulcanism and channel formation on Mars
December 16	First worms appear
December 19	First fish
December 20	Plants begins colonization on Earth
December 21	First insects
December 22	First amphibians
December 23	First trees, first reptiles
December 24	First dinosaurs
December 26	First mammals
December 27	First birds
December 29	First primates
December 30	First hominids, giant mammals flourish
December 31	First humans

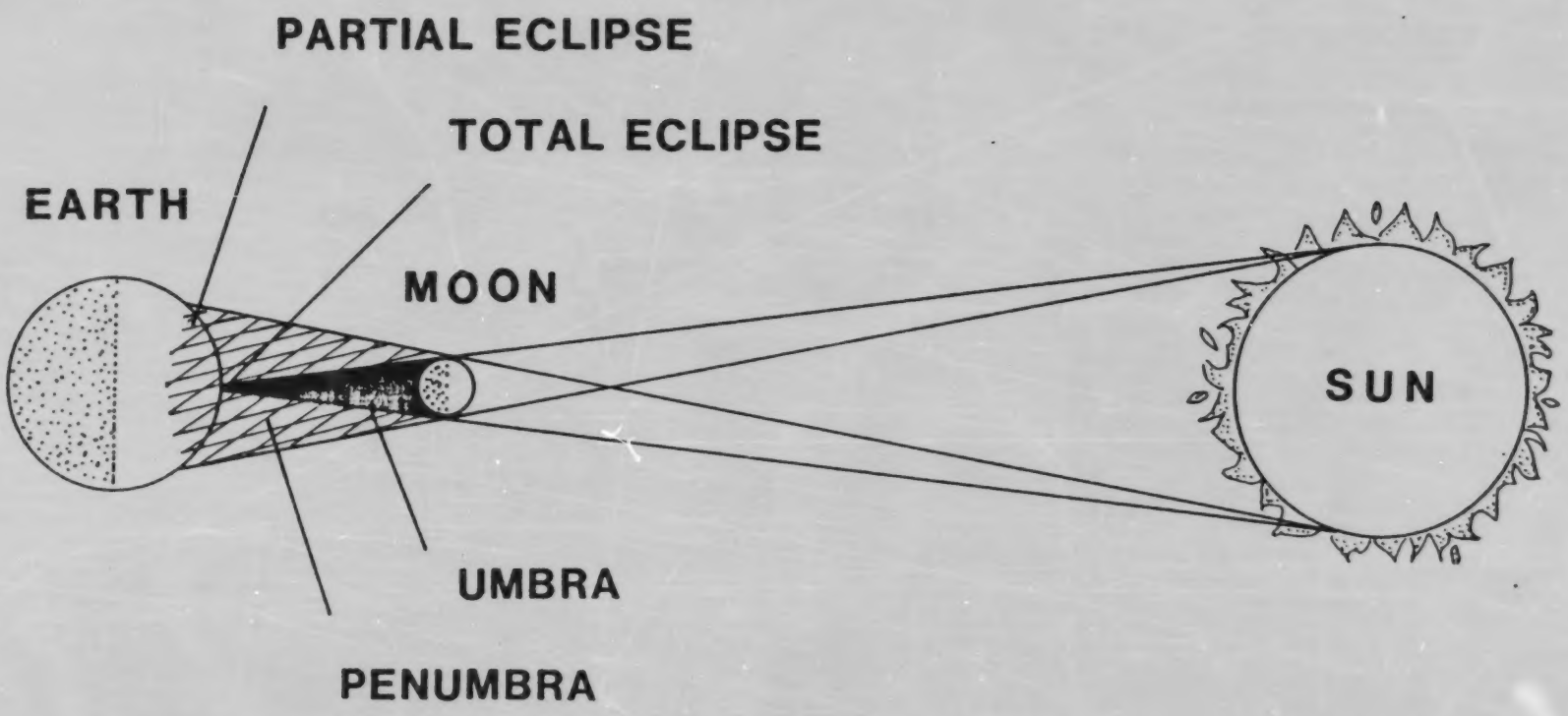
December 31

10:30p.m.	First humans
11:46p.m.	Domestication of fire by Peking man
11:56p.m.	Beginning of most recent glacial period
11:59:20p.m.	Invention of agriculture
11:59:35p.m.	First cities
11:59:53p.m.	Trojan Wars
11:59:56p.m.	Roman empire
11:59:57p.m.	Rome falls
11:59:58p.m.	Crusades
11:59:59p.m.	Renaissance in Europe, voyages of discovery from Europe
Now	Widespread development of science and technology, mankind
The first second of the New Year	acquires the means of self-distruction, first steps in planetary exploration and the search for extraterrestrial intelligence

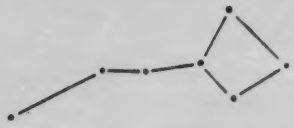
LUNAR ECLIPSE



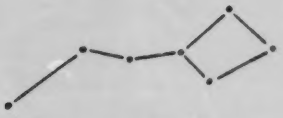
SOLAR ECLIPSE



BIG DIPPER THROUGH THE AGES

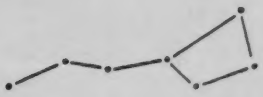


100,000 YEARS AGO

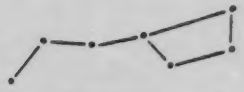


50,000 YEARS AGO

25,000 YEARS AGO

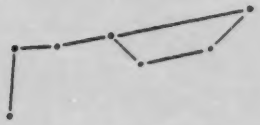


TODAY



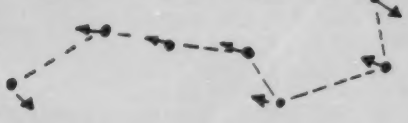
25,000 YEARS FROM NOW

50,000 YEARS FROM NOW



100,000 YEARS FROM NOW

DIRECTION OF THE STARS



LOST ON THE MOON

Your spaceship has just crash-landed on the moon. You were scheduled to rendezvous with a mother ship 200 miles away on the lighter surface of the moon, but the rough landing has ruined your ship and destroyed all the equipment on board, except for the 15 items listed below.

Your crew's survival depends on reaching the mother ship, so you must choose the most critical items available for the 200-mile trip. Your task is to rank the 15 items in terms of their importance for survival. Place number one by the most important item, number two by the second most important, and so on through number 15, the least important.

Difference	NASA		
_____	_____	_____	Box of matches
_____	_____	_____	Food concentrate
_____	_____	_____	Fifty feet of nylon rope
_____	_____	_____	Parachute silk
_____	_____	_____	Solar-powered portable heating unit
_____	_____	_____	Two .45-caliber pistols
_____	_____	_____	One case of dehydrated milk
_____	_____	_____	Two 100-pound tanks of oxygen
_____	_____	_____	Stellar map (of the moon's constellation)
_____	_____	_____	Magnetic compass
_____	_____	_____	Five gallons of water
_____	_____	_____	Signal flares
_____	_____	_____	First-aid kit containing injection needles
_____	_____	_____	Solar-powered FM receiver-transmitter
_____	_____	_____	Self-inflating life raft

LOST ON THE MOON (Key)

Items	NASA's Reasoning	NASA's Rank
Box of matches	No oxygen on moon to sustain flame, useless	15
Food concentrate	Efficient means of supplying energy requirements	4
Fifty feet of nylon rope	Useful in scaling cliffs, tying injured together	6
Solar-powered portable heating unit	Only used on dark side	13
Two .45 caliber pistols	Possible means of self-propulsion	11
One case of dehydrated Pet milk	Bulkier duplication of food concentrate	12
Two 100 pound tanks of oxygen	Most pressing survival need	1
Stellar map (of the moon's constellation)	Primary means of navigation	3
Self-inflating life raft	CO_2 bottle in military raft may be used for propulsion	9
Magnetic compass	Magnetic field on moon is not polarized; worthless for navigation	14
Five gallons of water	Replacement of tremendous liquid loss on lighted side	2
Signal flares	Distress signal when other ship is sighted	10
First aid kit containing injection needles	Needles for vitamins, medicines etc., will fit special hole in NASA space suits	7
Solar powered FM receiver-transmitter	For communication with mother ship; but FM requires line-of-sight transmission and short range	5
Parachute silk	Can be used as sling or dressings for injuries	8

Error points are the difference between your rank and NASA's.

Scoring

0-25	excellent	46-55	fair
26-32	good	56-70	poor
33-45	average	71-112	very poor, suggest possible faking or use of earth bound logic.

FIND 9 PLANETS

A N W D N S F F T M Q

A A U D N U C O W A S

C E B F D N U M L S R

H O O C V A P E Y U A

O T T T O R N L F N M

F U R L H U L K S E C

L L S A T U R N R V H

E P T P E Y Y C Z S R

R R E T I P U J N M H

Q N Z P T R W Z L R T

R O B H Y Z I D A S L

EARTH

JUPITER

MARS

MERCURY

NEPTUNE

PLUTO

SATURN

URANUS

VENUS

FIND 12 CONSTELLATIONS OF THE ZODIACS

M H R S A H L S N M S I I E K D S Z

L R A D F S A E R U F X E S M T J Y

A S M D K Y C T O E A Y E L J D Y N

W S A H S A M H C G T C S S C U L T

T A M B H U A R I Y S E M A U R D U

T E E U D T R N R I I P N D D G A R

A O E N L T U U P R D L B D S T D R

N V D D G A T S A G I T T A R I U S

H L R X M N H Q C T S D S A U N E T

G Z I C A P U A E O D C G T T G E F

O E N B E A N N S U R H J A V T T Y

F O M V R C M U F U D P N O Y O L C

H B I I E A I F X F R O I G C A Y U

N E U R N D E A R O H E D O A W S I

M S A G W I V H E K I A S S T O U B

T D C O S I L B N P F N N Y I B R P

AQUARIUS

ARIES

CANCER

CAPRICORN

GEMINI

LEO

LIBRA

PISCES

SAGITTARIUS

SCORPIO

TAURUS

VIRGO

FIND 15 STARS

V E A L T F D G A N M S I R I U S A

D Y D G U D D O I T S I Y M I J Z Y

Z R D R A Q N N A T I R I S K G T E

B W H W N W A Y C U H A U H P E E Q

B A N I R O D A Q O E L R G W S E L

T M H R E W N N A P U O Z N S N R N

B S T N X S C D S G L P A S A D O H

L E T S A R E A E U W U I S U N Y N

E U N O Y C O R P B T K M Y M S A S

C N H E I A E W A E F T N L V A A I

U A I D D D N P B T L P S E E C T A

U E E G H C C L O E N L G P N E U B

R H N A R A B E D L A A A L C M F D

P U U N T S F U X G L O L R A F W O

B E O I P T Q H A E F U U T L I D F

Y N E I I O D F U U T A X F A W R N

S D C F D R R N S S E B T I E I J H

E A V M U Y U K N E J X E S V A R R

ALDEBARAN

ALTAIR

ANTARES

BETELGEUSE

CAPELLA

CASTOR

DENEB

POLARIS

POLLUX

PROCYON

REGULUS

RIGEL

SIRIUS

SPICA

VEGA

FIND 5 NORTH POLAR CONSTELLATIONS

A T A R C F G D D S N L

I X H W E O H R O H D R

D M G U P P R H B I A O

R O L M H O P O T L I I

V I M G E C H I M R E A

W H C E U A C N D H P F

S F O W S R O E D G O A

R E P P I D E L T T I L

D H E Y Y O T W U H S B

R L F T Y C C O Y R S N

K M U N X H L D A R A Y

I U K M C S S A R A C S

BIGDIPPER

CASSIOPEIA

CEPHEUS

DRACO

LITTLEDIPPER

FIND 15 HAPPENINGS IN THE SOLAR SYSTEM

R B F H A L O L C O I N S

G S X X I I D O S U T B N

P X J N J F M L Y A R L Y

D H K S Y E B U S L A N W

H G A S T D I U E Y V H J

N C D S R E F N T E F D H

K A R P E O N I I O G L M

P A F A Y S E A L N E N C

T E M S T T L T L H E B N

D I M G M E I U E P I W E

H R L N T A R V T M D H W

S D I O R E T S A B O E W

H H S O I R G U S R C N N

D M R I M N I N G L G M R

O Y A T I Y A S I H N R A

A I T R I L D P Q C N U F

X G F G E W S O R B I T S

M Y N T R E G T A T E M M

O H M U N L L S N D Z H E

ASTEROIDS
COMETS
CRATERS
ECLIPSE
GRAVITY
LIFE
MARE
METEORS
ORBITS
PHASES
PLANETS
RINGS
SATELLITES
SUN
SUNSPOTS

FIND 14 HAPPENINGS OUTSIDE THE SOLAR SYSTEM

S A E F Z K N K B C A O N A S D L I M P D E O I T H E N R

T I M Y I C H C Y J R W A S T T S S T T E F P E K C O N T

F F T D C W B M M T O M L W A I N I E N R I F O W N D Y G

T F M O D Q D A S G A S O E R M I A P D K Y B V F J N I A

H O H P A S O E E V O P Q M S M B R I N A Y S M D E C U H

I N N A A O L A E H C N T O D E S A E G L C S I C N I O E

O N O Y O M O D P S W S D S X C A W U P D N I L H N B F U

G H T M O T F S R A D H D A R A T N H M O E T K U O M C F

V H T H D I K D Z L O S M F N S N N B I N A R Y S T A R S

A N D H F E I R U E K O O E D D G P T S T W H W E D A Q I

W S D C O T L E I A D E M O R D N A E L L E E A H H L Z E

H R N E P N E D S S U H K X B B L O L D D K D Y O Y C Z T

H I F G X F U Y F R B O A Y S L N R V A T O S W S H S S T

D N N T N F W H U A E B L U E U A Q A A X I C U A E H C Z

M R N M T O T R E S L T Q T P E Q C H W E I B T L R U R N

L N B E G O H L H A P T S O A G I X K Y T C E E O F F B A

S R A T S N O R T U E N U N U I T E O H F G C S T O F S U

I J L X R T Q L L Q O D G M R A S T W L O B K O W P S X L

U O P H H T O S N C T T S F C N F T A N Y L N R A M H E N

K E E F A T A L P G O H T N T T H U T N L Q E E N O Y Q D

A E E I R R H K S D M D T A F S A R H E S T Q S K H M R B

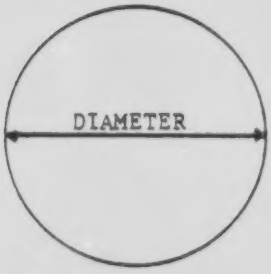
G Z H R S E J D P G R X I P H U F W U K O M E D G L U R T

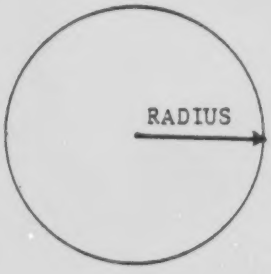
ANDROMEDA
BINARYSTARS
BLACKHOLES
BLUEGIANTS
CONSTELLATIONS
GALAXIES
MILKYWAY
NEUTRONSTARS
NOVAE
PULSARS
QUASARS
REDGIANTS
STARS
WHITEDWARFS

RADIUS & DIAMETER

The diameter is the distance across the circle.

The radius is the distance from the center of the circle to the outside of the circle.





The radius is always one half the diameter

Questions:

1) Here are the diameters of circles, you give the radius.

   Diameter is 10 cm, radius is 5 cm

   Diameter is 16 cm, radius is ___ cm

   Diameter is 8.4cm, radius is ___ cm

   Diameter is 7.2cm, radius is ___ cm

2) Given the radius figure out the diameter for a circle.

   Radius is 7 cm, diameter is 14 cm

   Radius is 5.3cm, diameter is ___ cm

   Radius is 3.2cm, diameter is ___ cm

   Radius is 2.1cm, diameter is ___ cm

3) Using a radius of 3 cm, draw a circle.

4) Draw a circle that will have a diameter of 4.8 cm.

MAKING SCALE DIAGRAMS OF THE SOLAR SYSTEM

Complete the following table using a scale of 1 centimeter for every 10,000 kilometers. This means that you will be reducing the size of the planets.

PLANETS AND SOME LARGE SATELLITES	ACTUAL DIAMETER IN KILOMETERS (KM)	SCALE DIAMETER (CM)	SCALE RADIUS (CM)
Mercury	4,900	.49	.25 (divide by 2)
Venus	12,100		
Earth	12,800		
Moon	3,500		
Mars	6,800		
Jupiter	143,000		
Io	3,700		
Europa	2,900		
Ganymede	5,500		
Collisto	4,500		
Saturn	120,000		
Titan	4,800		
Uranus	50,800		
Neptune	48,600		
Pluto	5,800		

On the following page draw the scaled planets and satellites using the proper dots.

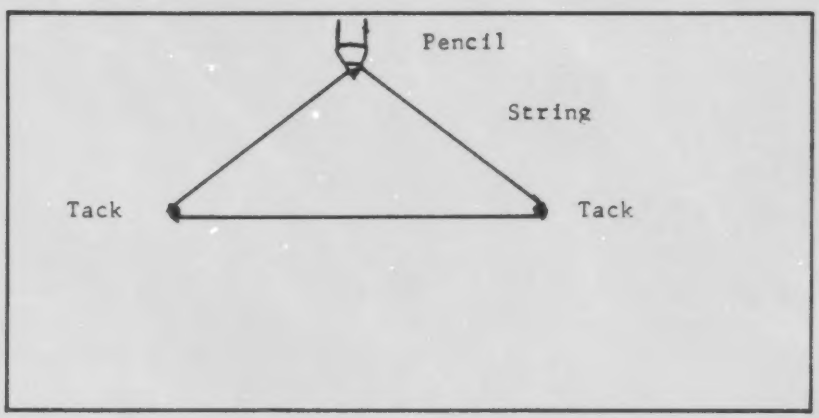
Mercury
Venus
Earth
Moon
Io
Europa
Jupiter
Ganymede
Collisto
Mars
Uranus
Saturn
Titan
Neptune
Pluto

ELLIPSES

To draw an ellipse you need the following:

- 2 thumbtacks
- pencil
- string
- metric ruler
- cardboard or wooden platform
- white drawing paper

1. Place a sheet of white drawing paper on the top of a cardboard or wooden platform
2. In the middle of the paper, place 2 thumbtacks 6 cm. apart.
3. Ties the ends of a string together forming a loop with a circumference of 20 cm.
4. Loop the string tightly around the thumbtacks and stretch it tightly using a pencil.
5. Trace out the path followed by the pencil around the thumbtacks keeping the string tightly stretched at all times.



6. The figure drawn is called an ellipse. The thumbtacks are the focus points. Label these points A and B. Label three points anywhere on the ellipse C_1, C_2, and C_3.
7. Measure the lengths of the lines AC_1; AC_2; AC_3; BC_1; BC_2; and BC_3 in mm. and fill in the chart on the following page.

Position of C	Length of AC (mm)	Length of BC (mm)	Sum of AC and BC (mm)
C_1			
C_2			
C_3			

8. Draw another ellipse with the focus points 3 cm. apart instead of 6 cm. Repeat the procedure done in Step 7 and complete the following chart.

Position of C	Length of AC (mm)	Length of BC (mm)	Sum of AC and BC (mm)
C_1			
C_2			
C_3			

9. Compare the results and what general statement can be said with regard to the sum of any two lines drawn from the focus point to any point on an ellipse.

ORBITS OF THE PLANETS

This activity use the procedures learned in the activity on drawing an ellipse and applies it to drawing a scale model of the solar system.

The materials you need are the following:

- 2 thumbtacks
- string
- cardboard
- 2 pieces of drawing paper
- metric ruler

1. Set use the materials used to draw an ellipse.
2. Using the table below giving string loop sizes and distances between tacks, draw concentric ellipses showing the paths travelled by the planets around the Sun.

Note:
Due to the immense differences in distances between the inner and outer planets it is not practical to use the same scale for all planets. Use one sheet of paper for the inner planets and one for the outer planets.

The Inner Planets (Scale: 1cm = 15,000,000 km)

Planet	Loop Size	Distance Between Tacks
Mercury	9.0 cm	1.50 cm
Venus	14.0 cm	0.08 cm
Earth	19.0 cm	0.32 cm
Mars	31.5 cm	2.70 cm

The Outer Planets (Scale: 1 cm = 300,000,000 km)

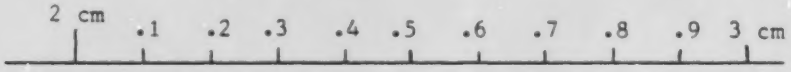
Jupiter	5.2 cm	0.24 cm
Saturn	9.5 cm	0.48 cm
Uranus	19.0 cm	0.88 cm
Neptune	28.8 cm	0.32 cm
Pluto	46.7 cm	9.50 cm

READING FROM A METRIC RULER

In the metric system everything is based on multiples of 10 so it is easier to use decimals instead of fractions. (1 centimetre=10 millimetres, 1 metre=100 centimetres, etc.)

It is simple for you to think of decimal readings (like 2.5 cm) as a whole number and a fraction of 10 (like 2 5/10) because:

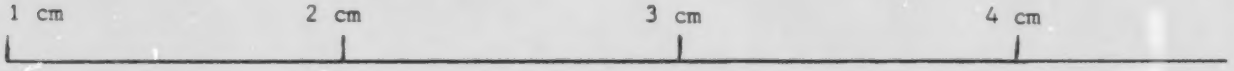
.1=1/10, .2=2/10, .3=3/10, .4=4/10 and so on



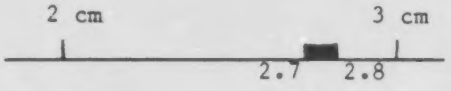
1/10 2/10 3/10 4/10 5/10 6/10 7/10 8/10 9/10

ACTIVITY 1: On this enlarged view of a metric ruler, mark the following points:

a) 1.8cm b) 2.1cm c) 2.4cm d) 2.7cm e) 2.65cm
f) 2.77cm



To mark a point like 2.77cm on a ruler, you first have to find the area between 2.7cm and 2.8cm.



Now you have to divide that small area into 10 equal parts and find the 7th space in there to give you 2.77cm.

ACTIVITY 2: On this enlarged ruler find the following points:

a) 7.27cm b) 7.42cm c) 7.51cm d) 7.48 e) 7.64cm
f) 7.39cm

SCALE OF PLANETARY DISTANCES

Fill in this sheet to show the scale of distances from the Sun and the diameters of the planets. You will use a scale of 10,000,000 km = 1 cm. Note that according to this scale, the planets are not bigger than pinheads

PLANET	ACTUAL DIAMETER (kilometres)	SCALE DIAMETER (centimetres)	ACTUAL DISTANCE (kilometres)	SCALE DISTANCE (centimetres)
Sun	1,390,000	.139	-	-
Mercury	4,900		57,900,000	5.79
Venus	12,100		108,100,000	
Earth	12,800		149,000,000	
Mars	6,800		228,000,000	
Jupiter	143,000		778,000,000	
Saturn	120,000		1,430,000,000	
Uranus	50,800		2,870,000,000	
Neptune	48,600		4,500,000,000	
Pluto	5,800		5,900,000,000	

HINT: You are using a scale of 10,000,000 km = 1 cm so divide every number by 10,000,000

10 000 000 ⟌ 1 390 000 .139

10 000 000 ⟌ 57 900 000 5.79

move the decimal point 7 places

WHAT HAPPENS TO A SPINNING FLEXIBLE BALL?

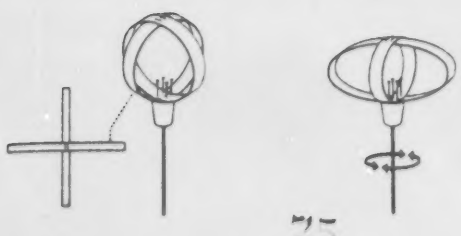
You need the following items:

- a strip of cardboard 30cm long and about 2cm wide
- scotch tape
- a small rubber band

1. Make a circle of the cardboard and fasten the ends with scotch tape.
2. Make two holes at opposite ends of the circle. Make one hole of a size that the pencil fits tightly. The other hole should provide a loose fit for the pencil.
3. Wrap a small rubber band about 4cm from the eraser end.
4. Attach the cardboard ring to the pencil with the smaller hole going on first.
5. Hold the pencil between the palms of your hands and spin it. What happens to the cardboard ring?

The earth is spinning on its axis. It makes one rotation every 24 hours. The earth's circumference at the equator is very large. Therefore, at the equator, the earth is spinning at a speed of about 1600 km per hour. Scientists believe that the bulging of the earth is due to its force of rotation.

ANOTHER SET UP



PLANETARY ORBITS

This exercise studies the motion of an object moving in an elliptical path around a star

The materials you need are the following: - a protractor

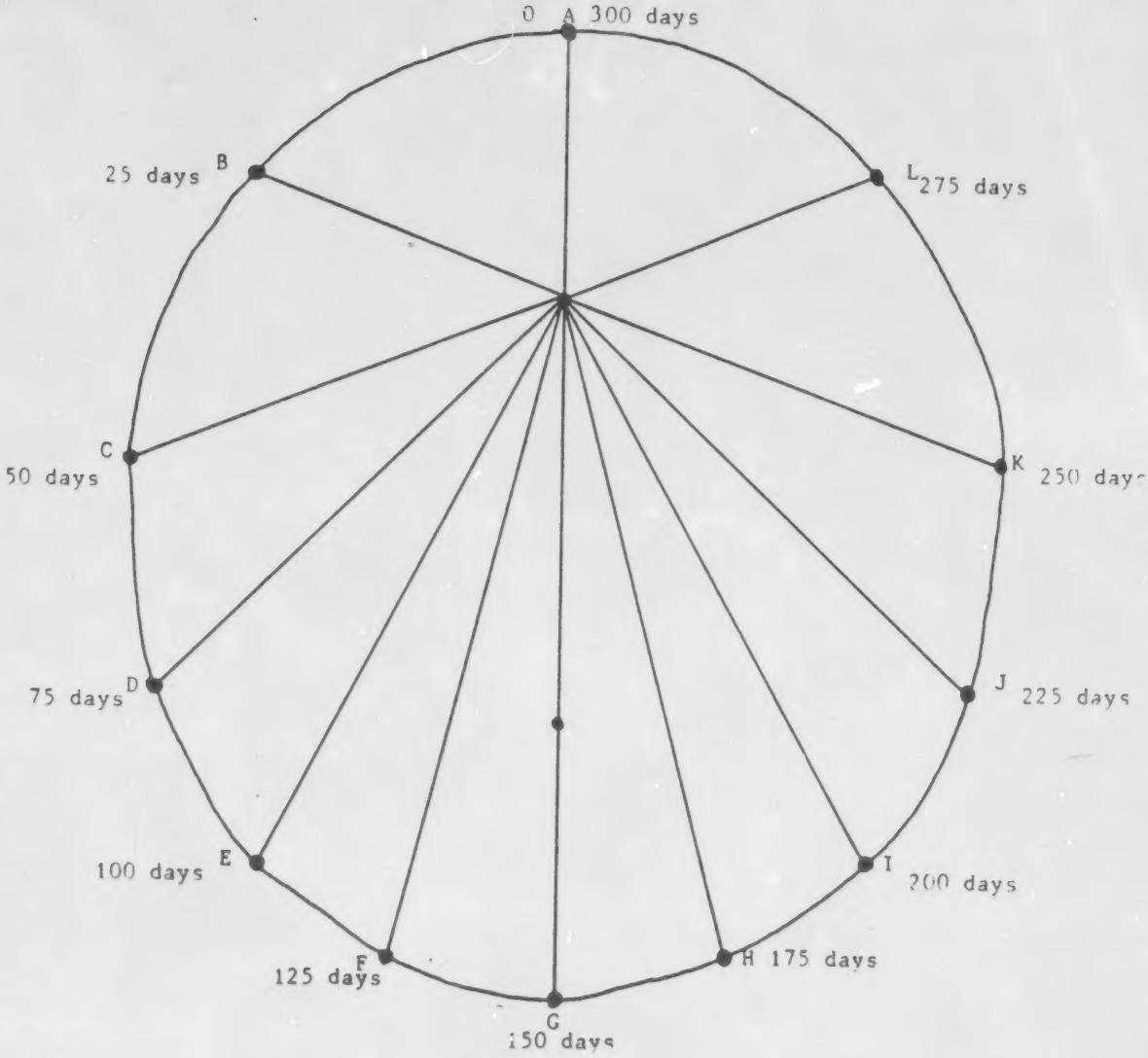
1. Look at the page entitled "The Orbit of Planet X". This planet moves around its star in 300 days. Positions of the planet are marked off in 25 day intervals.

2. Using a protractor measure the angles formed from the focus where the star is to the position of the planet every 25 days. Record your results in the data table below.

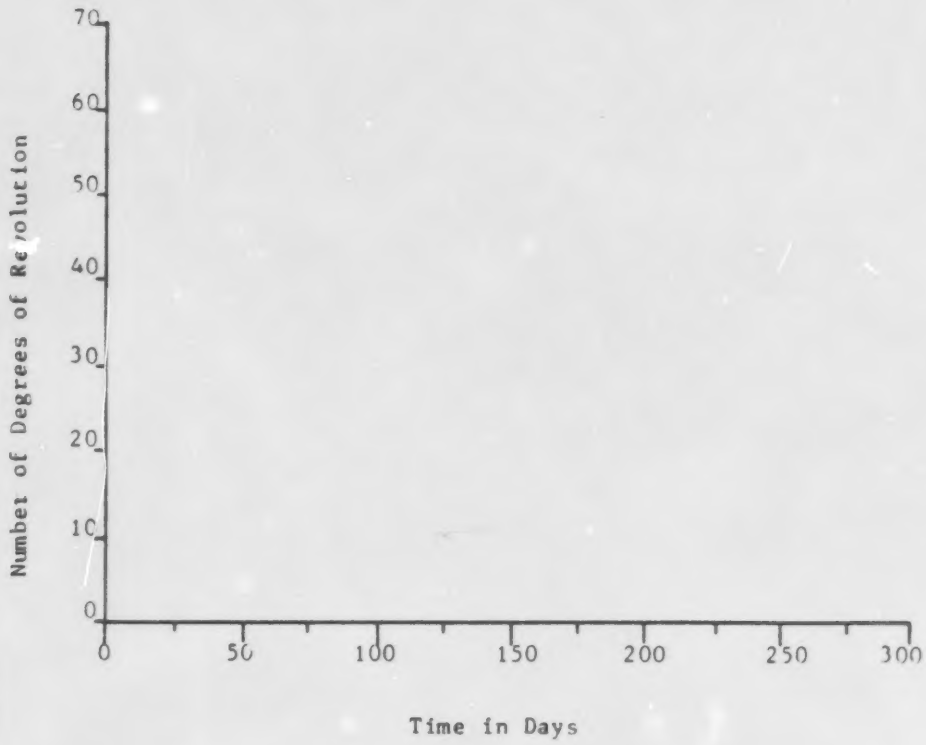
DATA TABLE

Time Travelled (25 day intervals)	Number of Degrees Moved
A-B	
B-C	
C-D	
D-E	
E-F	
F-G	
G-H	
H-I	
I-J	
J-K	
K-L	
L-A	

The Orbit of Planet X



Graph the results on the graph below:



Questions:

1. At what position is the planet at perihelion? _____
2. At what position is the planet at aphelion? _____
3. At which point in its orbit is it travelling the fastest? _____
4. At which point in its orbit is it travelling the slowest? _____

COLOUR TEMPERATURE RELATIONSHIP OF STARS

When an object produces its own light, we call that object luminous. The colour of a luminous objects tells us what temperture it is. For example, an object which is a dull red colour is not as hot as an object which is bright red. A luminous object which is yellow in colour is much hotter than a bright red object. If the colour of a luminous object is white, then the temperature is very, very hot. The hoyyest of all luminous objects is blue-white.

If two objects are yellow, they may not have exactly the same colour. One may be dark yellow while the other may be a light yellow. This is the same with stars. All yellow stars are not the same yellow. The exact colour depends upon the star's temperature.

In astronomy, we can distinguish a white star and a blue-white star, or a yellow star from a red star, by the use of the star's spectrum. It is not easy for our eyes to distinguish between the various colours of the stars. The spectrum is very sensitive. We assign the following letters to the stars to tell us the star's spectral class (its colour):

W O B A F G K M N S

You can remember these letters this way:

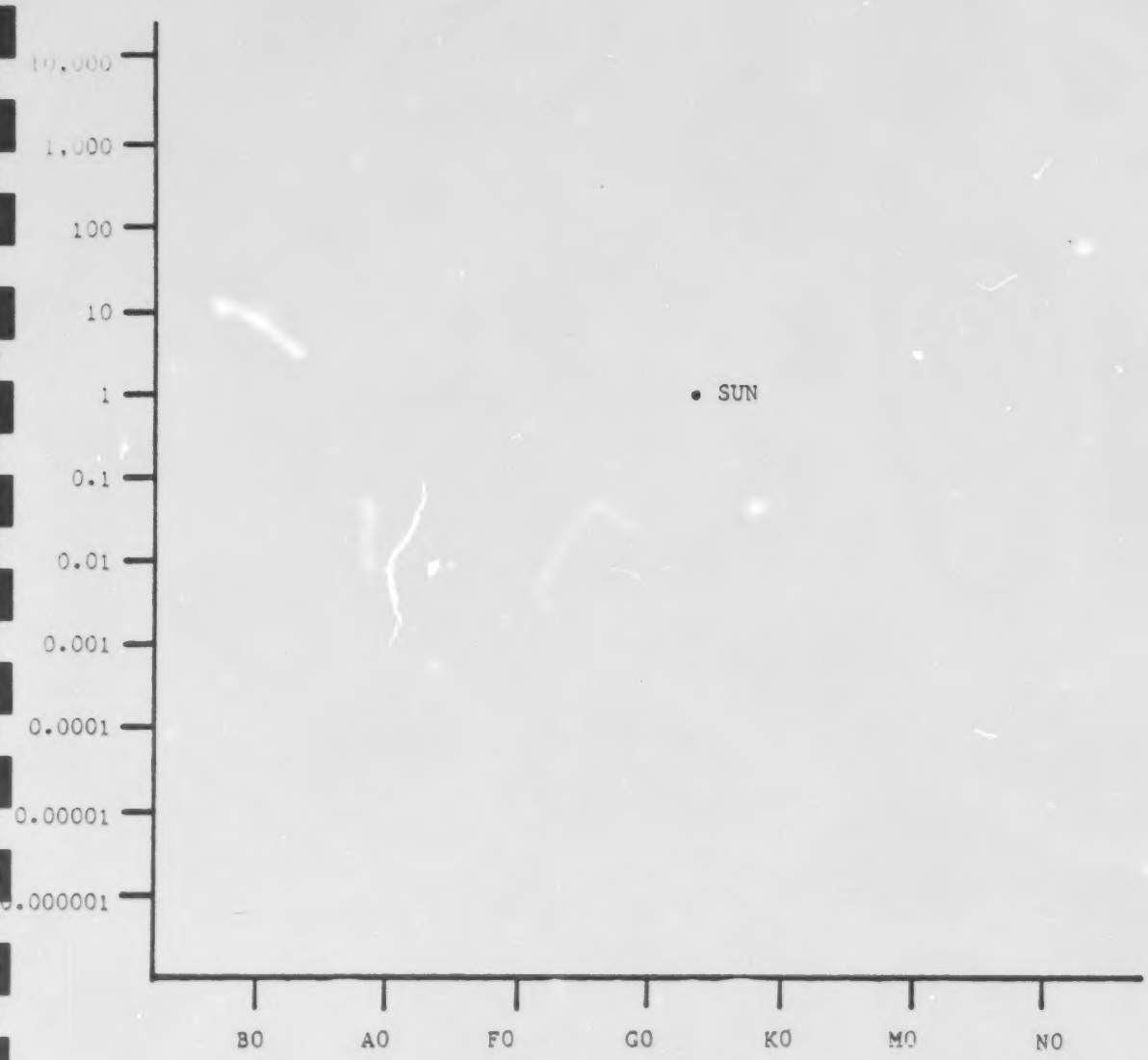
Wow O Be A Fine Girl Kiss Me Now Sweetie

A super hot blue-white star is a W star.
A very hot white star is an O star.
A hot white star is a B star.
A yellow star like our Sun is a G star.
Hot red stars are M stars, and cool red stars are N and S stars.

For each of the stars listed on the next page, line up the luminosity with the spectral class on the graph provided. Notice how the dot for the Sun matches 1 for luminosity and G for spectral class. Do not write the names of each of the stars on the graph.

STAR	TEMPERATURE IN °K	NUMBER OF TIMES THE SUN'S LUMINOSITY	SPECTRAL TYPE
Sirius	10,000	23	A1
Canopus	7,000	1,500	F0
Alpha Centauri	5,800	1.3	G2
Arcturus	4,500	90	K2
Vega	10,700	60	A0
Capella	5,900	150	G0
Rigel	11,800	40,000	B8
Procyon A	6,500	7.6	F5
Betelgeuse	3,200	17,000	M2
Achernar	14,000	200	B3
Beta Centauri	21,000	3,300	B1
Altair	8,000	10	A7
Alpha Crucis	21,000	2,700	B1
Aldebaran	4,200	90	K5
Spica	21,000	1,900	B1
Antares	3,400	4,400	M1
Pollux	4,900	3,300	K0
Fomalhaut	9,500	14	A3
Deneb	9,900	40,000	A2
Beta Crucis	22,000	6,000	B0.5
Regulus		70	A0
Alpha Centauri A	5,800	1.3	G2
B	4,200	0.36	K5
C	2,800	0.00006	M5
Barnard's Star	2,800	0.00044	M5
Wolf 359	2,700	0.00002	M4
Lalande 21185	3,200	0.0052	M2
Sirius A	10,400	23	A1
B	10,700	0.008	A2
Luyten 726-8A	2,700	0.00006	M6
726-8B	2,700	0.00004	M6
Ross 154	2,800	0.0004	M5
248	2,700	0.00011	M6
128	2,800	0.00033	M5
Epsilon Eridani	4,500	0.30	K2
Luyten 789-6	2,700	0.00012	M6
61 Cygni A	4,200	0.083	K5
61 Cygni B	3,900	0.040	K7
Procyon A	6,500	7.6	F5
Ptocyon B	7,400	0.0005	F2
Epsilon Indi	4,200	0.13	K5

LUMINOSITY VS. SPECTRAL CLASS

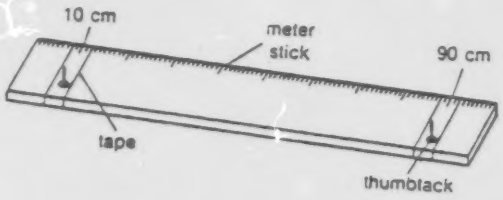


DISTANCE MEASURING DEVICE

To construct a distance measuring device you will need the following materials:

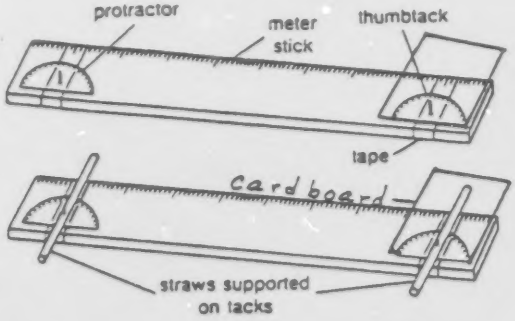
- a metre stick
- 2 thumbtacks
- 2 protractors
- masking tape
- one piece of cardboard 15cm^2 or larger
- 2 straws

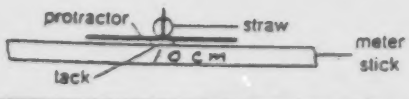
1. Place two thumbtacks upside down on a metre stick, one at the 10cm mark and one at the 90cm. Using the masking tape, stick them to the metre stick as in the diagram below:

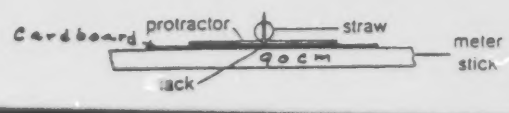


2. Place a protractor on the tack at the 10cm mark by drilling a small hole in the protractor to prevent it from breaking and putting the protractor over the tack. Tape the protractor down with masking tape so that it is parallel with the edge of the metre stick.

3. On the tack at the 90cm mark place a square piece of cardboard. Place a protractor on the top of the cardboard and tack and tape it down as in step 2.





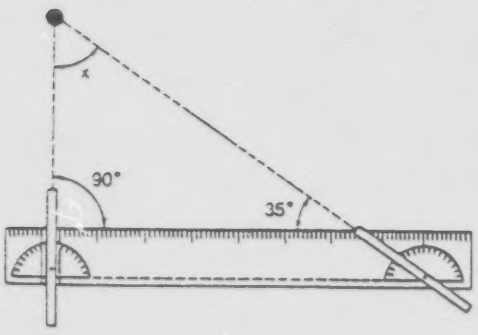


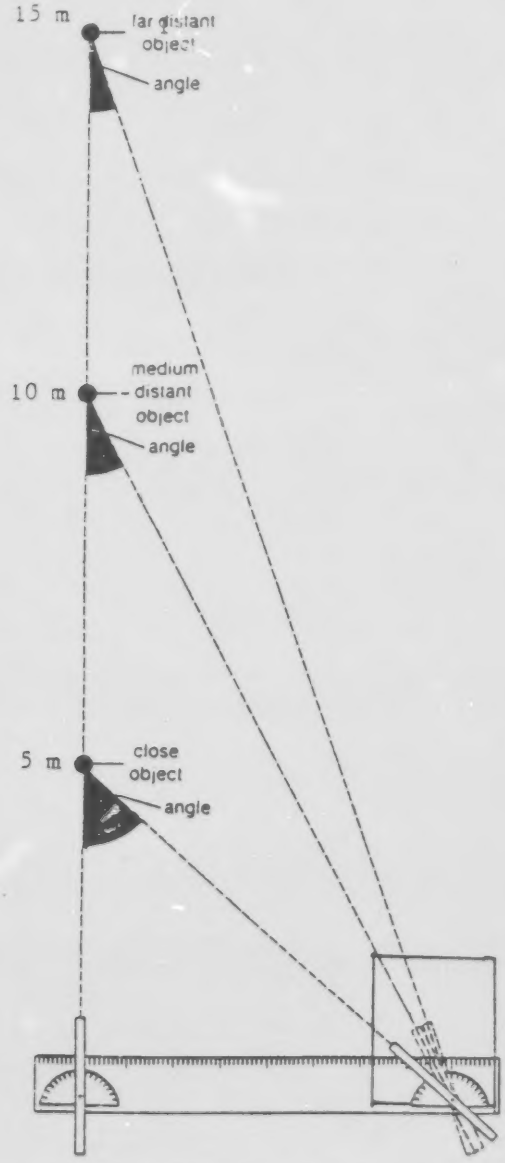
Calibration

To calibrate the distance measuring device, place objects at known distances of 1 metre, 3 metres, 5 metres, 10 metres, 15 metres and 20 metres from you.

1. Line the object 1 metre away from your distance measuring device so that the straw at the 10 cm mark lies directly on the top of the 90° mark of the protractor.

2. Line the straw at the 90 cm mark up with the object and place a mark on the cardboard directly underneath the straw. Record the information along with the angle (x) it marks with the base of the protractor. This angle is called the angle of parallax. An example is illustrated below:



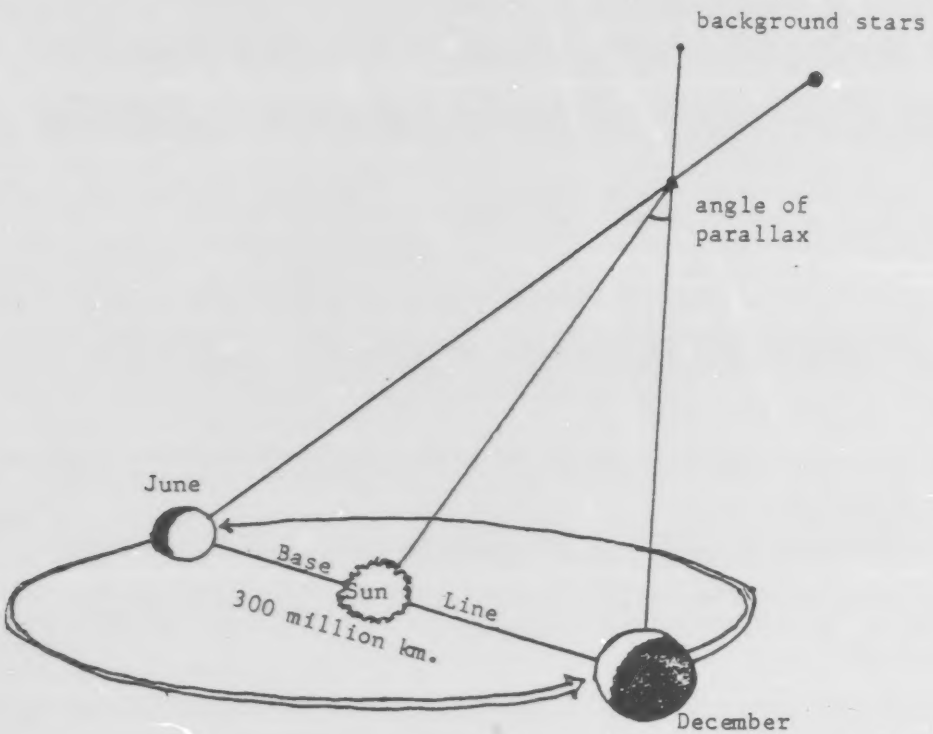


3. Repeat the above step for each of the known distances. Calibrate the cardboard with each of these distances and calculate the angle of parallax. Record your results in the following table.

DISTANCE MEASURED (METRES)	ANGLE AT 10 CM	ANGLE AT 90 CM	TOTAL	ANGLE OF PARALLAX
1				
3				
5				
10				
15				
20				

Measuring Distances to Stars

To measure distances as far away as stars an enormous base line is needed. The longest baseline possible is the distance across the orbit of earth. To use this distance astronomers sight stars six months apart. At six month intervals the earth is at opposite positions in its orbit. Even with this large base line the parallax effect is very small. It is possible to measure the distances to the nearest stars in this manner using very fine instruments.



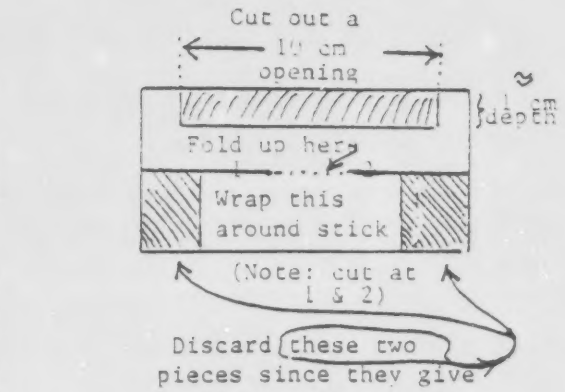
ANGLE MEASUREMENTS

MAKING A CROSS STAFF:

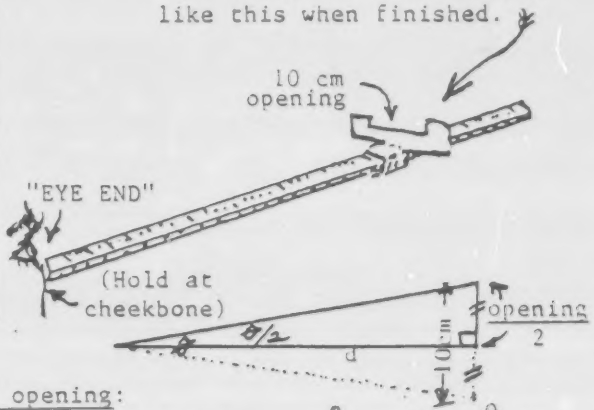
TABLE OF DISTANCES

Angle Subtended at the EYE by a 10 cm opening	Distance Along Staff from the EYE for a 10cm opening
50°	10.72 cm
40	13.74
30	18.66
24	23.52
20	28.36
18	31.57
16	35.58
14	40.72
12	47.57
10	57.15
9	63.53
8	71.51
7	81.75
6 (θ)	95.41 (d)

USING A 5" x 3" FILE CARD:



Discard these two pieces since they give problems with wrapping around the meter or yard stick. Tape the final wrapping so that the card will slide. It should look like this when finished.



For a 10 cm opening:

Formula: $d = \frac{\text{opening}}{2} \cot.\frac{\theta}{2} = 5\cot.\frac{\theta}{2}$ cm

STEP ONE:

Tape a double thickness of masking tape to a meter (or vard) stick. (double thickness helps hide the numbers written on the stick)

STEP TWO:

Using the table given above, mark on the tape the ANGLES, using the distance placements given in the table (e.g. a line for 30° would be made at a distance of 18.66 cm from the end marked "PLACE CHEEK HERE" which is the "eye" end. Mark the line 30°. Readings other than those in the table can be extrapolated, keeping in mind the changing scale.)

STEP THREE:

Using a 5" x 3" filing card, cut an opening of 10 cm along the side, and then cut and attach the card to the staff as shown above on the right.

STEP FOUR:

Your instructor will demonstrate both how to make the card and to use the "cross staff."

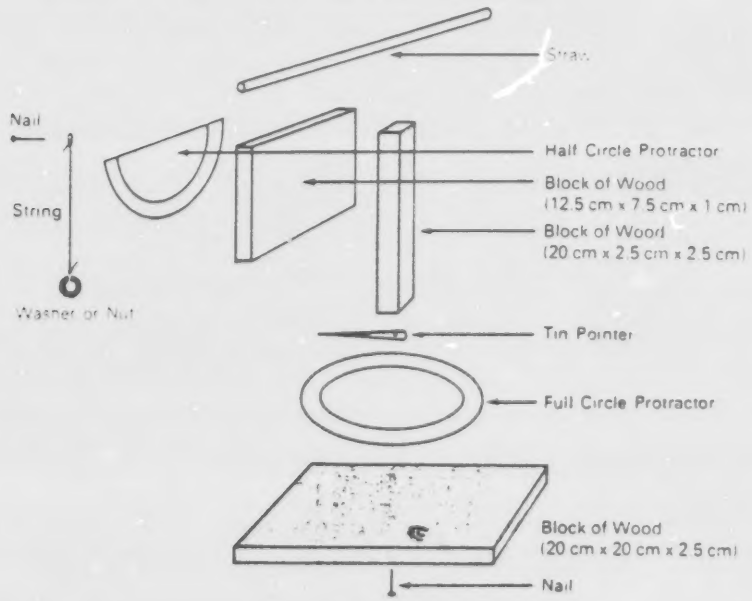
ASTROLABE

To construct an astrolabe, examine the diagram below and follow the steps listed below.

You need the following supplies:

- a 12.5cm x 7.5cm x 1cm block of wood
- a 20cm x 20cm x 2.5cm block of wood
- a 20cm x 2.5cm x 2.5cm piece of wood
- a milkshake straw
- a 15cm piece of thread
- a small metal washer
- a 1cm x 7.5cm piece of tin (tapered at one end)
- a paper half-circle protractor
- a paper full-circle protractor
- 2 elastic bands
- a 5cm nail
- a 4cm nail

EXPLODED SKETCH OF AN ASTROLABE



1. Cut out and glue the half-circle onto the 12.5cm x 7.5cm x 1cm block of wood as shown in the diagram.

2. Cut out and glue the full-circle pro ractor onto the 20cm x 20cm x 2.5cm piece of wood. To center the full-circle protractor correctly, draw lines on the block of wood from corner to corner making an X. Punch a hole in the center of the paper protractor and line it up with the center of the X on the piece of the wood.

3. Use two elastic bands to hold the straw on top of the 12.5cm x 7.5cm x 1cm block of wood.

4. Glue the broad end of the pointer to one end of the 20cm x 2.5cm x 2.5cm piece of wood.

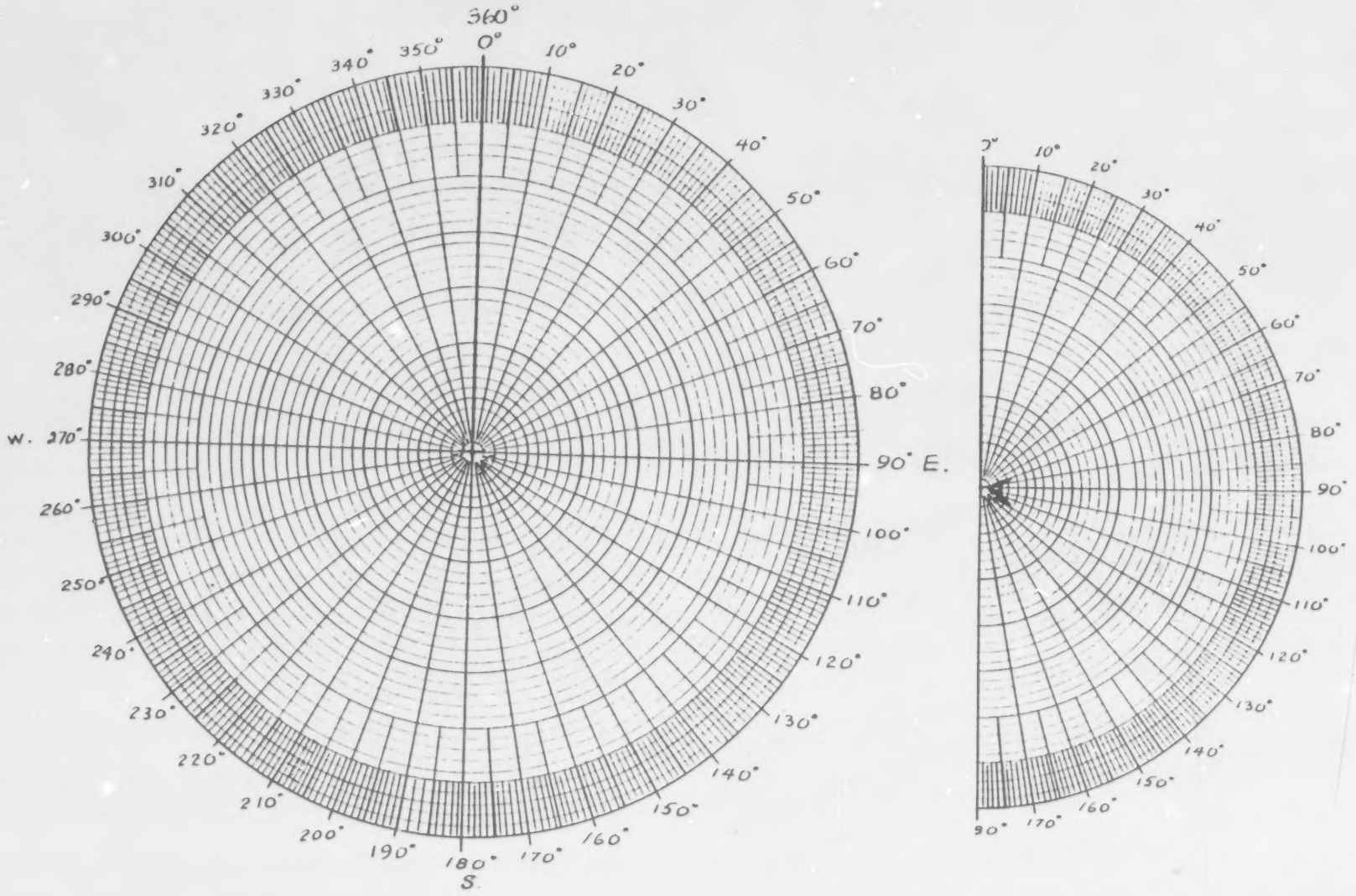
5. When the glue on the piece of tin has dried, take a nail and hammer and punch a hole through the tin and into the wood. Center the hole. Punching the hole in the tin will allow for easier assembly later.

6. Assemble the astrolabe by nailing the 12.5cm x 7.5cm x 1cm block of woodnear the top of the 20cm x 2.5cm x 2.5cm piece of wood with the 4cm nail. Hammer the nail directly through the part of the protractor labelled A. Leave a part of the nail protruding so that the piece of thread can be tied on it.

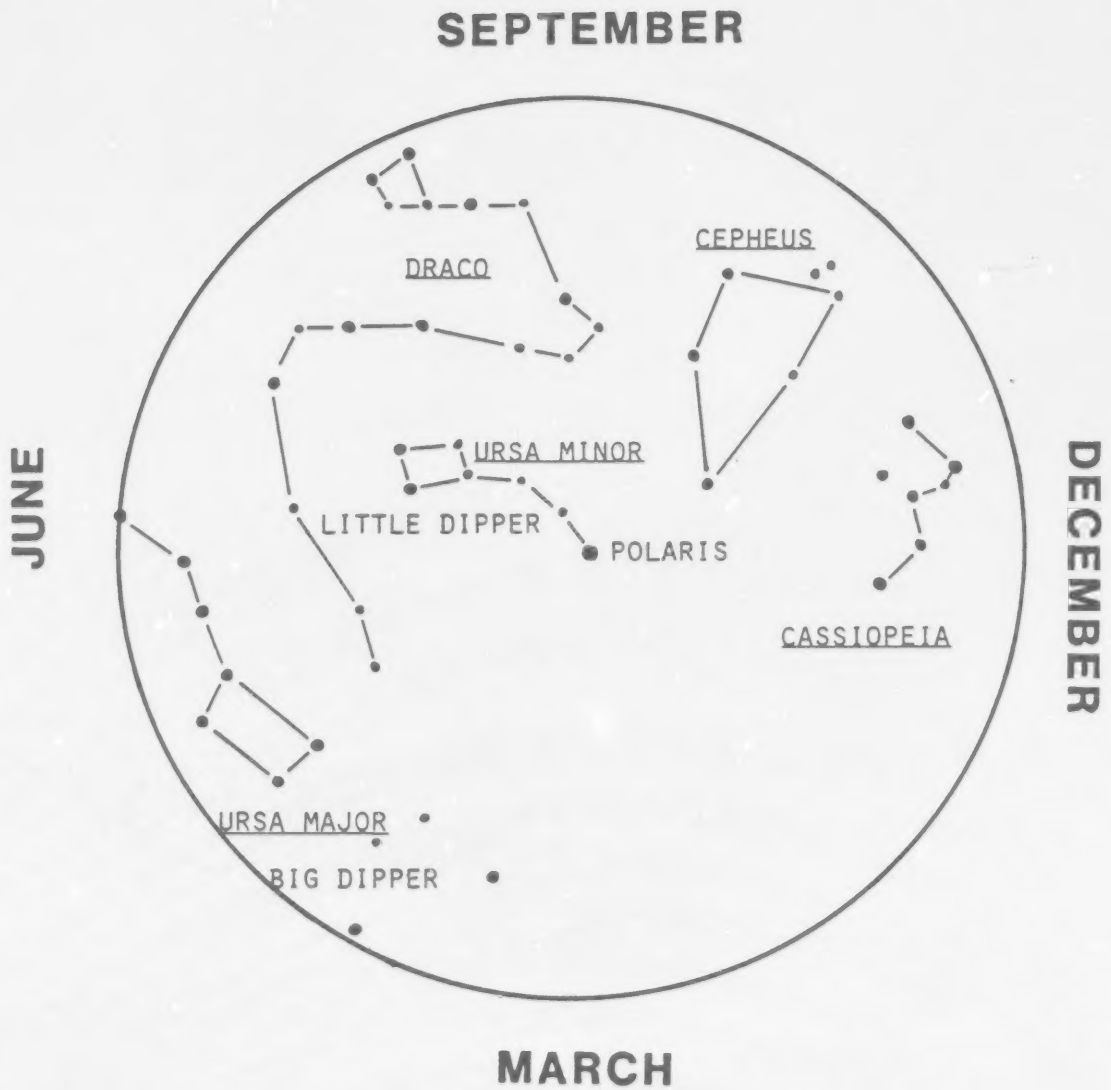
7. Nail the 20cm x 2.5cm x 2.5cm length of wood onto the 20cm x 20cm x 2.5cm piece of wood. Center the nail on the piece of wood.

8. Tie the metal washer to one end of the piece of thread and tie the other end of the thread to the nail hammered into point A on the half-circle protractor.

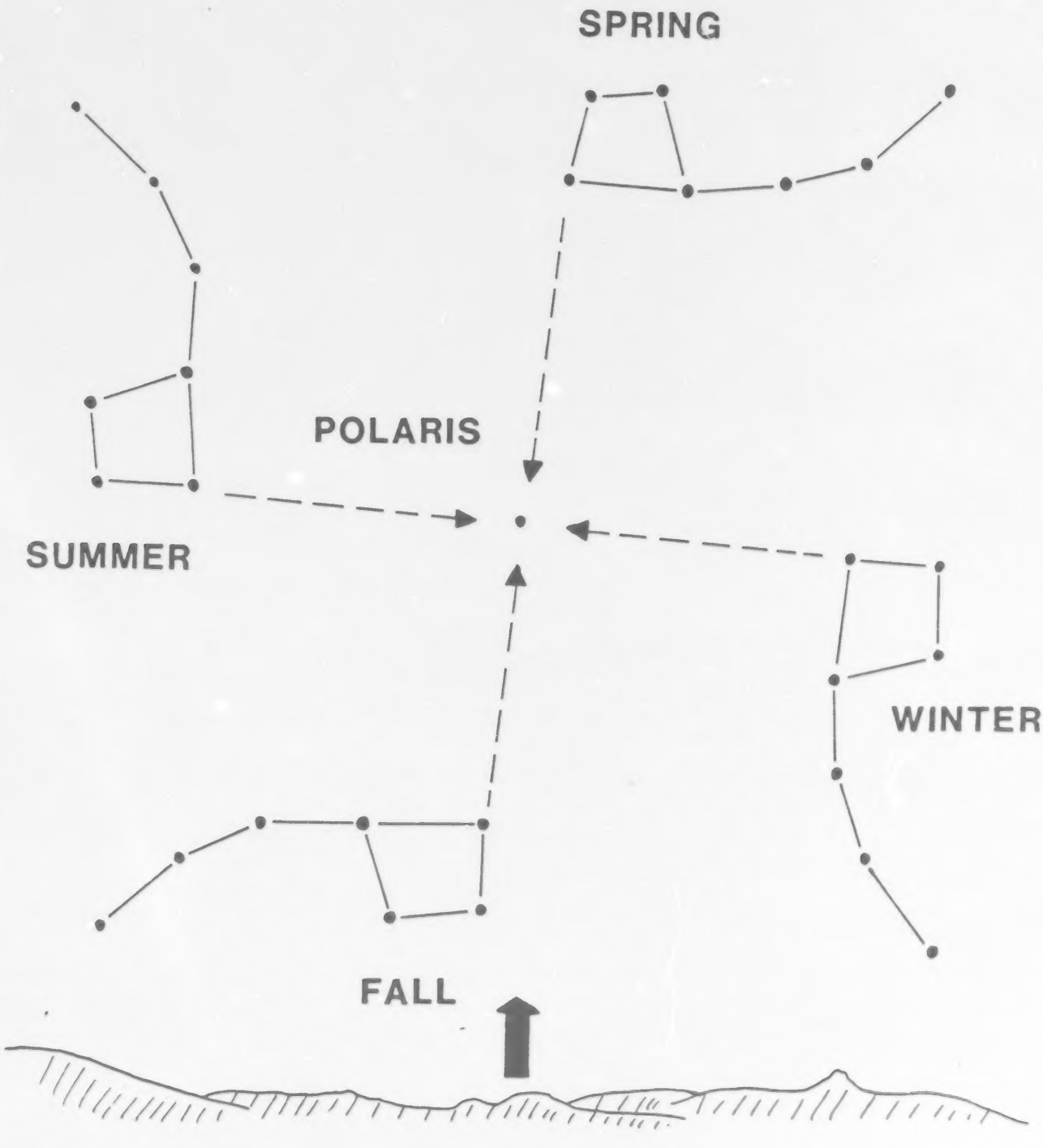
On a clear night take your astrolabe outside and place it on something level. Line up 0 on the full-circle protractor with true north. This can be done by sighting Polaris. Without moving the astrolabe from its base position, the top part can be swung around clockwise until the desired object in the sky can be sighted through the straw. Once the sighting has been taken the altitude can be obtained by reading the number directly behind the thread on the half-circle protractor. The azimuth can be obtained by reading the number directly at the end of the tin pointer on the full-circle protractor.


360°
0°
10°
20°
30°
40°
50°
60°
70°
80°
90° E.
100°
110°
120°
130°
140°
150°
160°
170°
180°
S.
190°
200°
210°
220°
230°
240°
250°
260°
W. 270°
280°
290°
300°
310°
320°
330°
340°
350°

NORTH POLAR CONSTELLATIONS



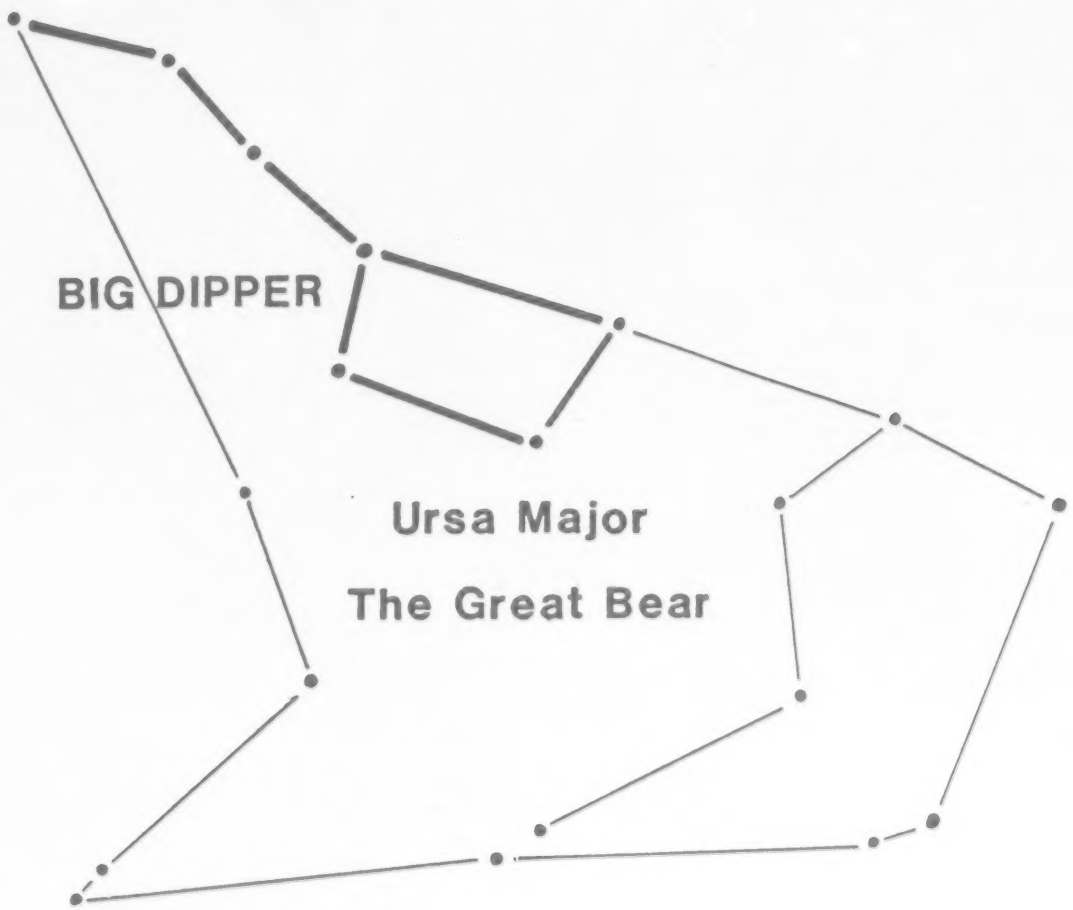
BIG DIPPER IN DIFFERENT SEASONS



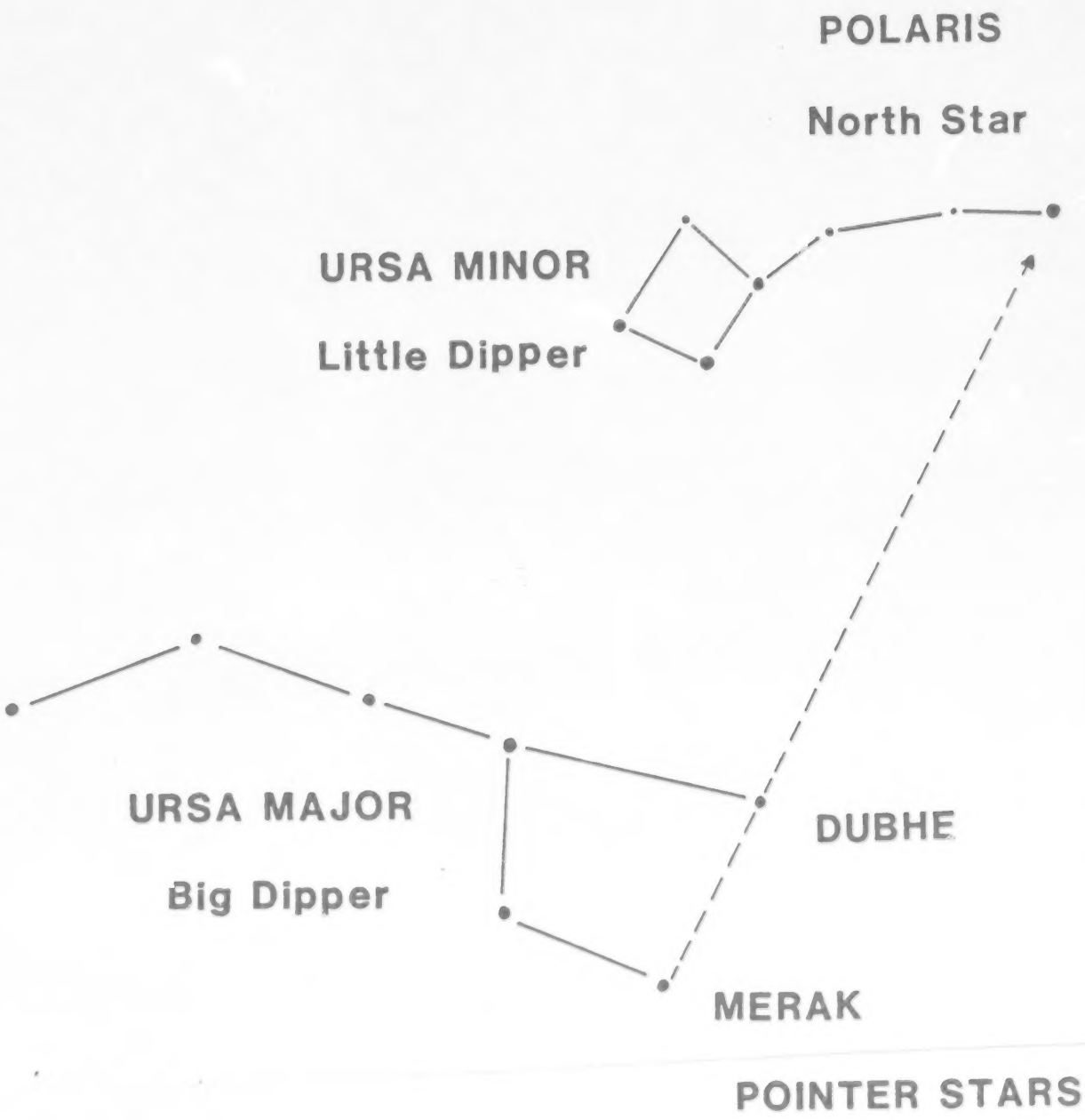
LOOKING NORTH AT EIGHT P.M.

THE BIG DIPPER

A Part of the Constellation Ursa Major

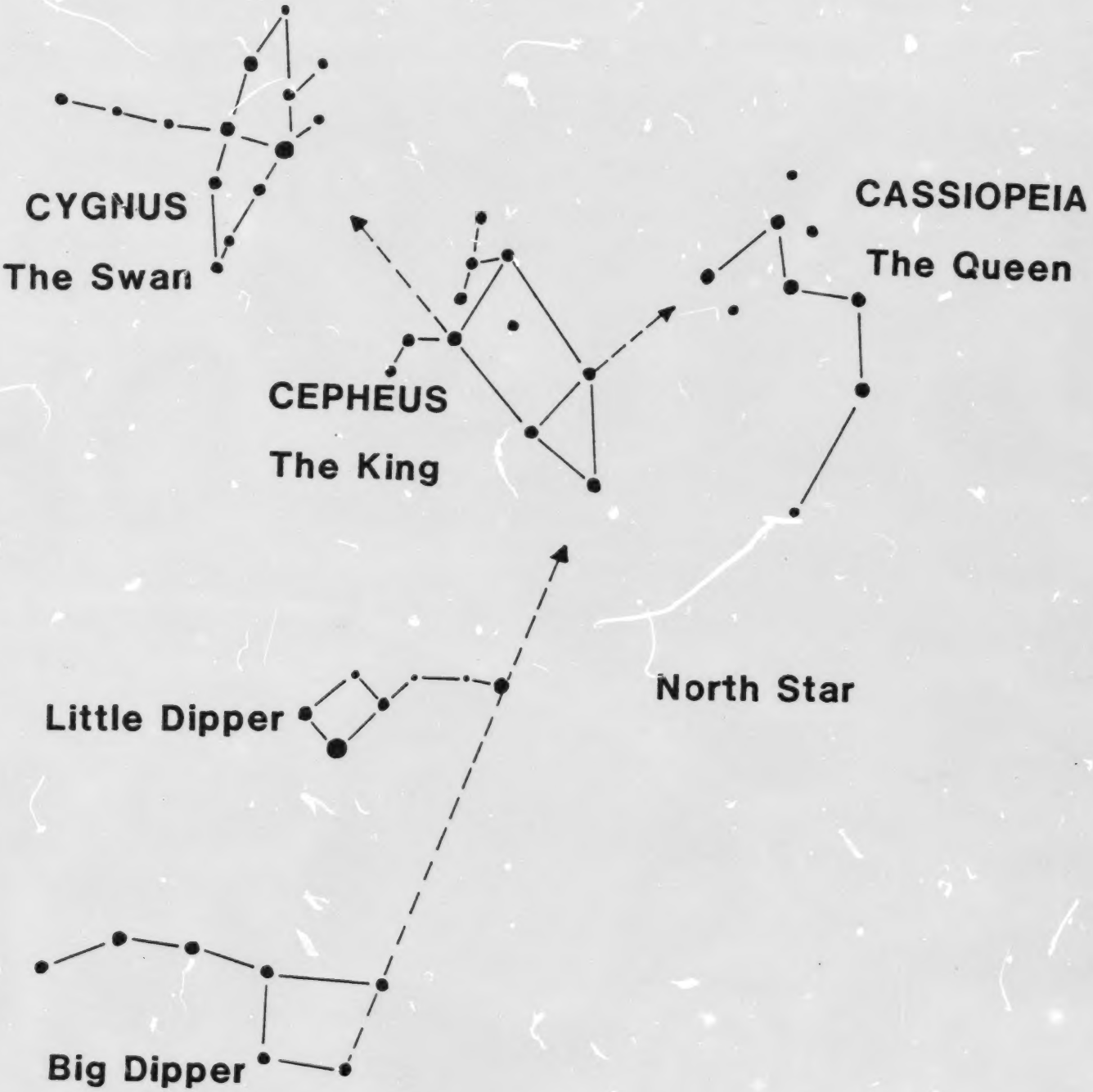


FINDING THE NORTH STAR

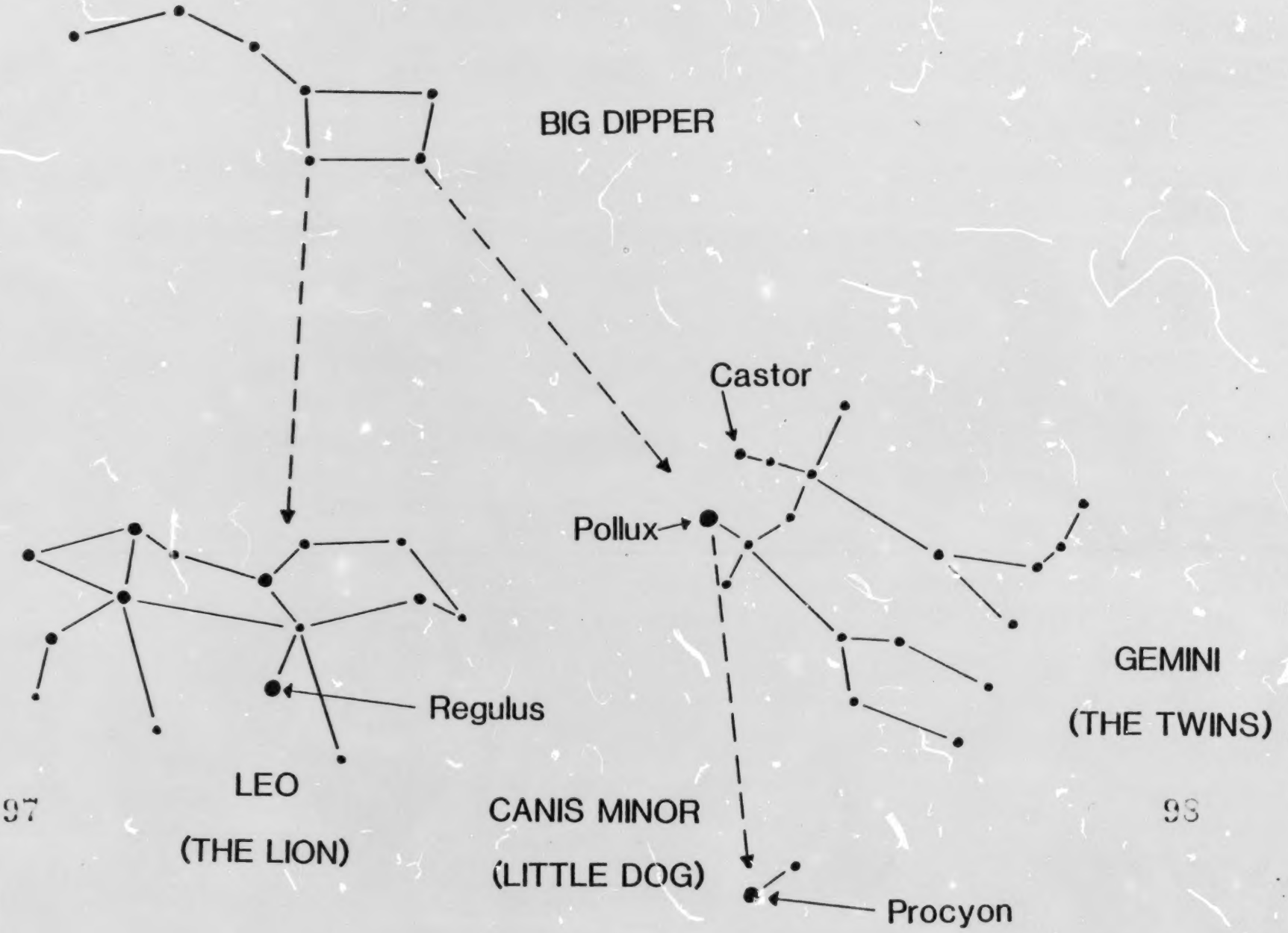


FINDING DRACO

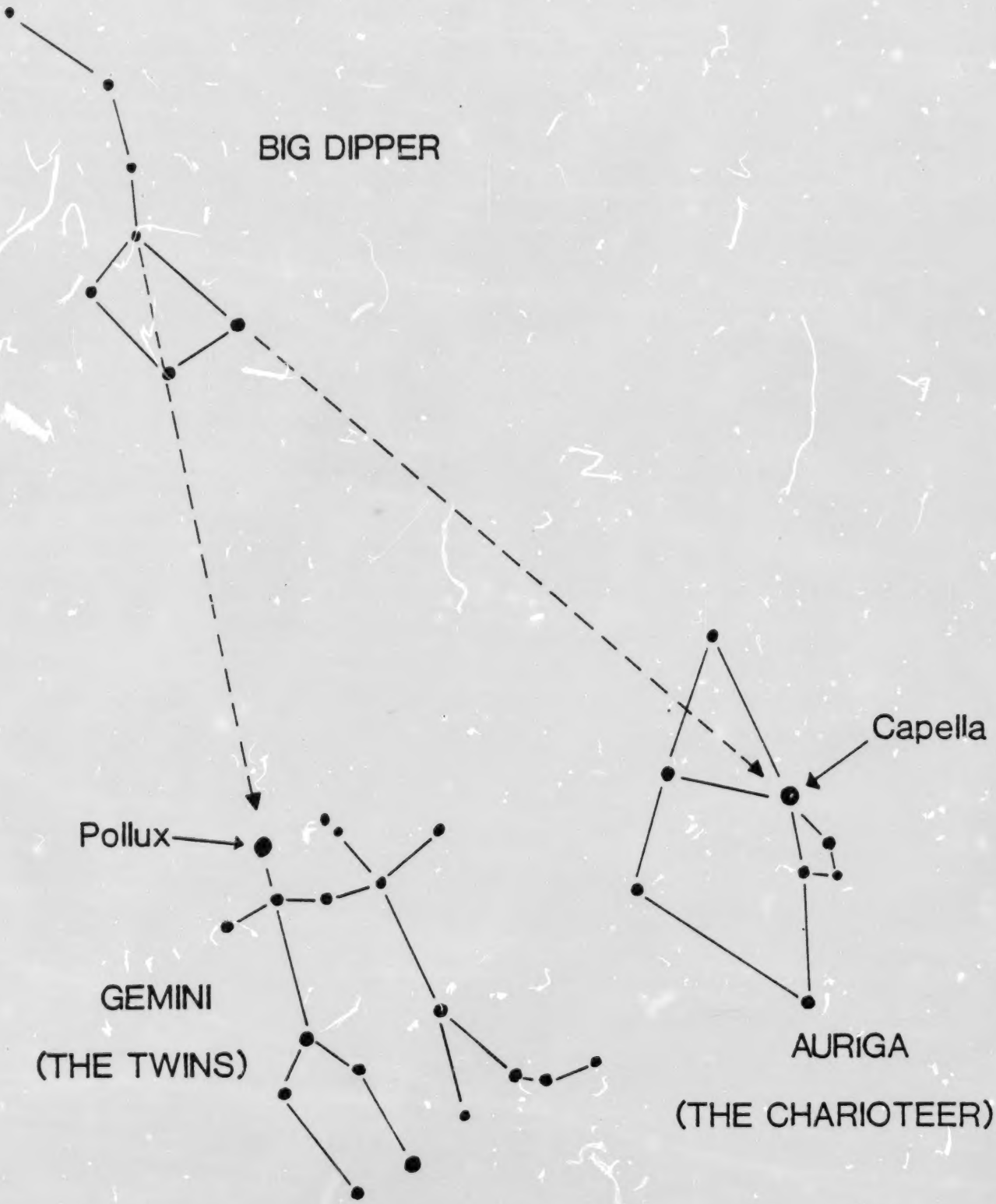
FINDING CEPHEUS, CASSIOPEIA, AND CYGNUS



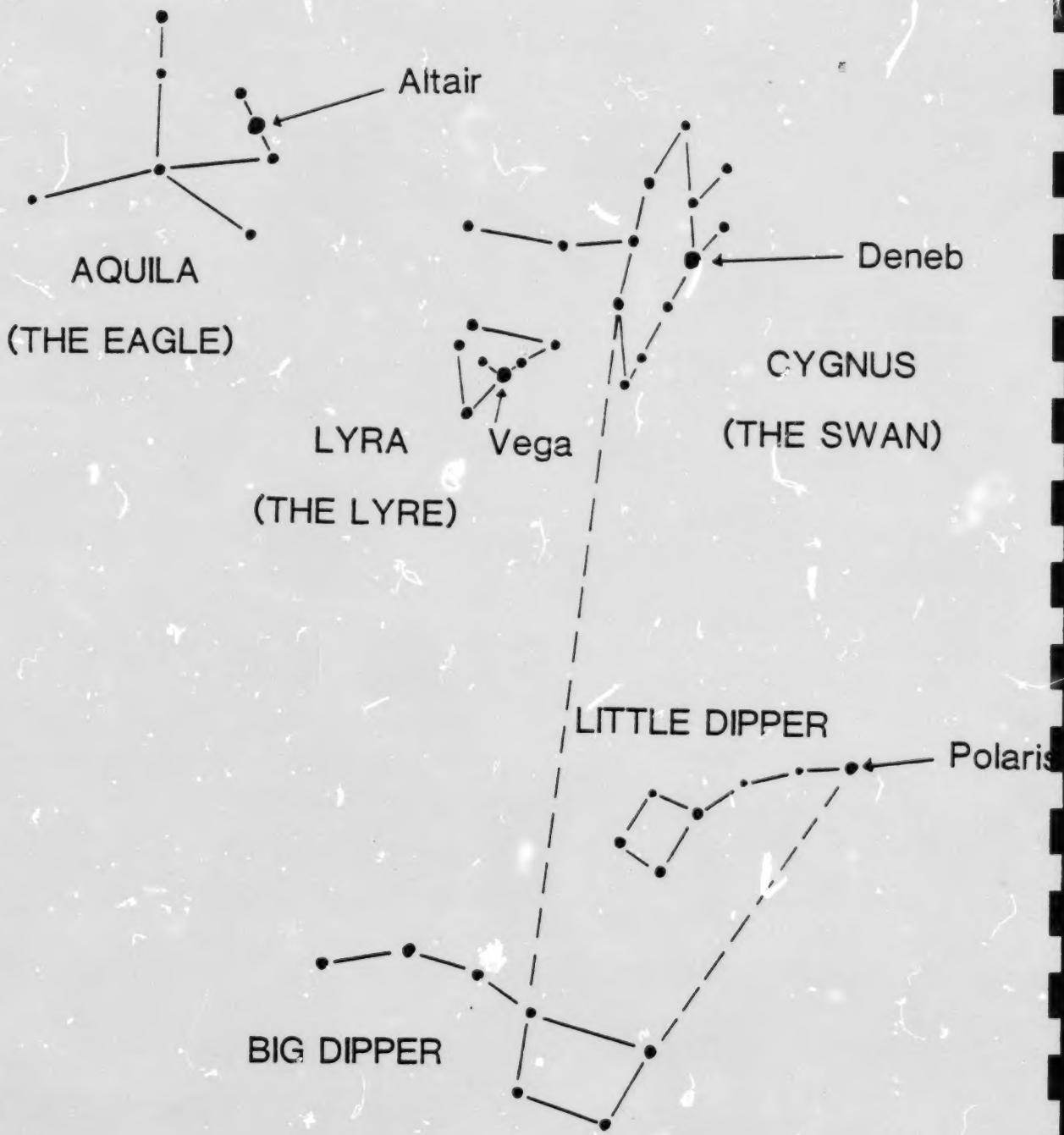
FINDING LEO, CANIS MINOR & GEMINI



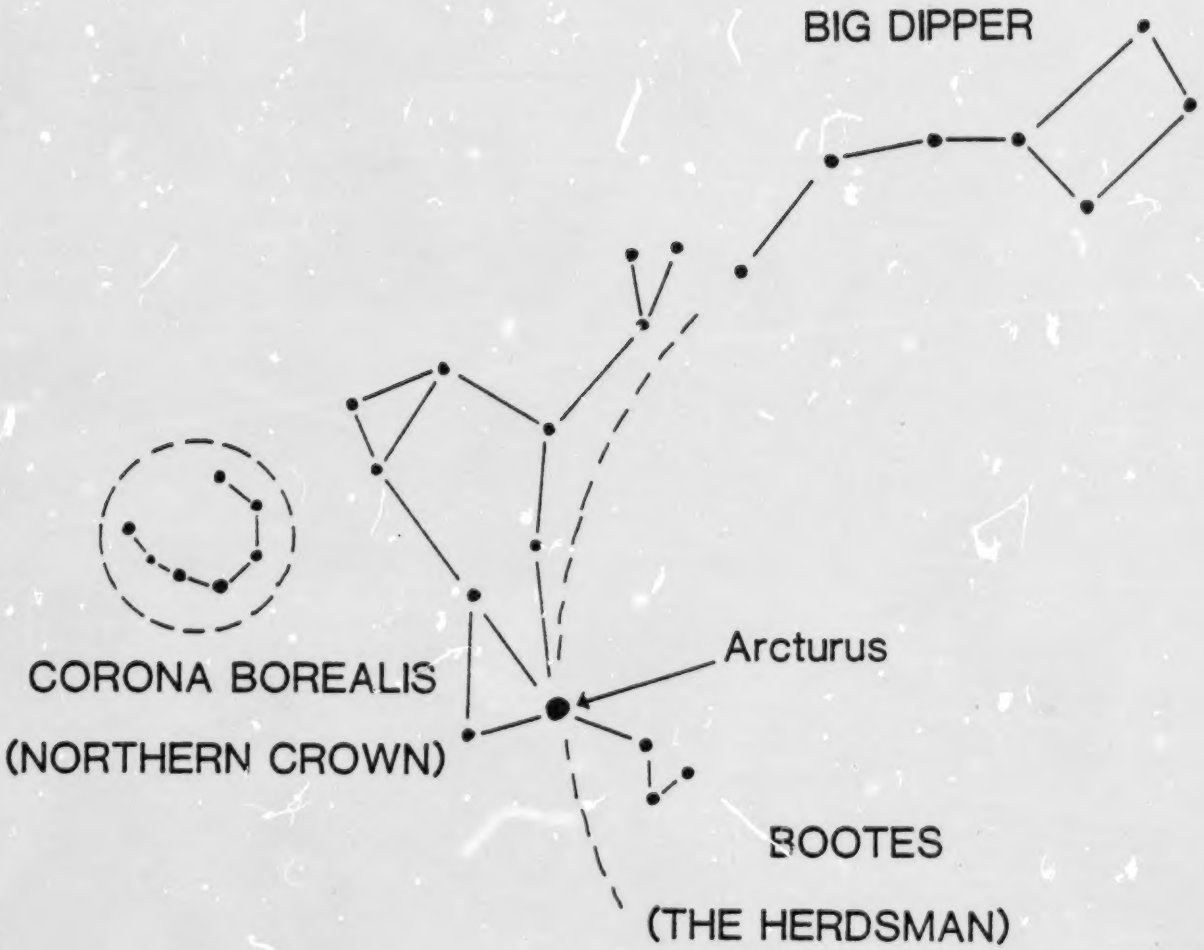
FINDING GEMINI & AURIGA



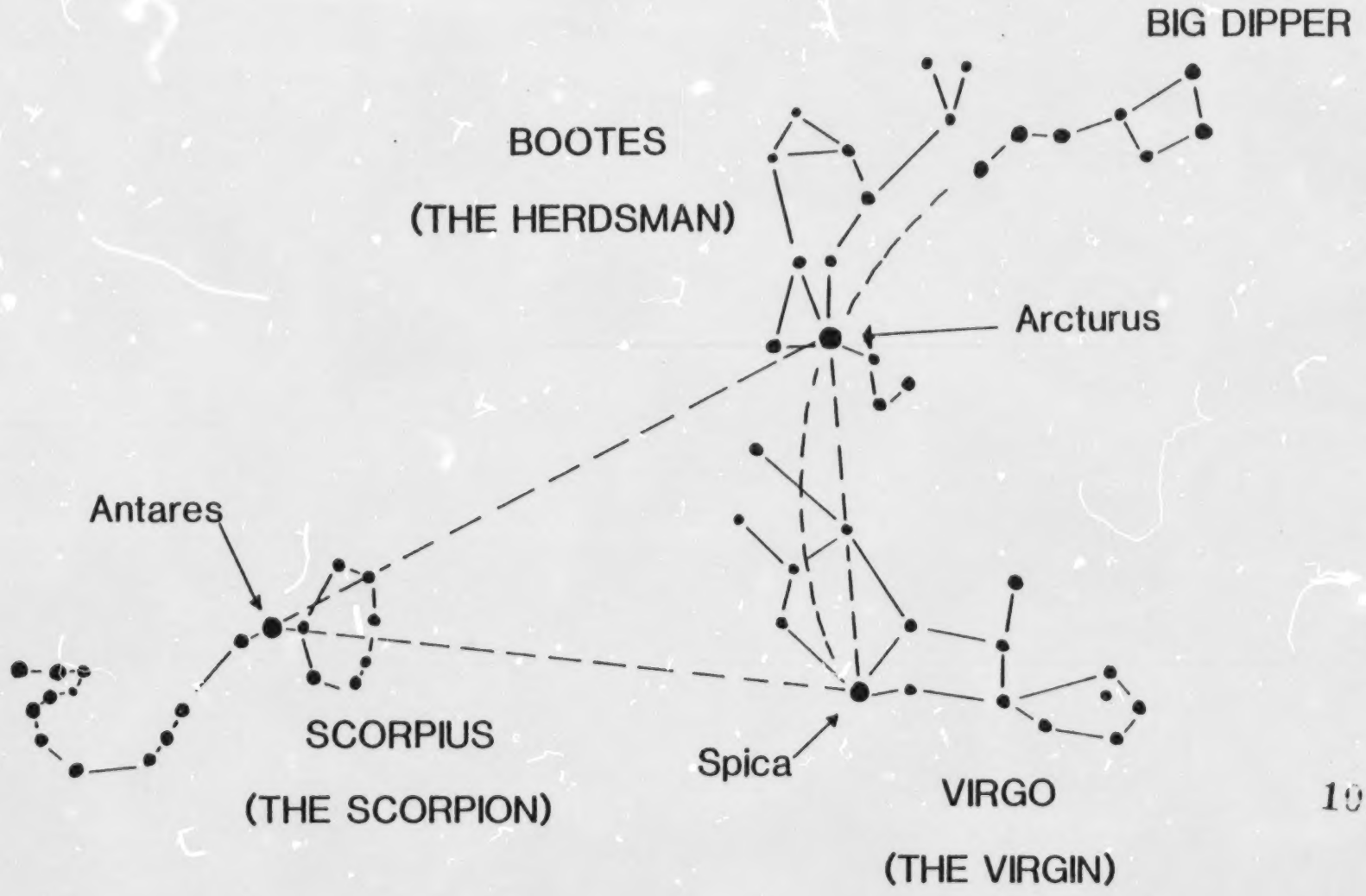
FINDING CYGNUS, LYRA & AQUILA



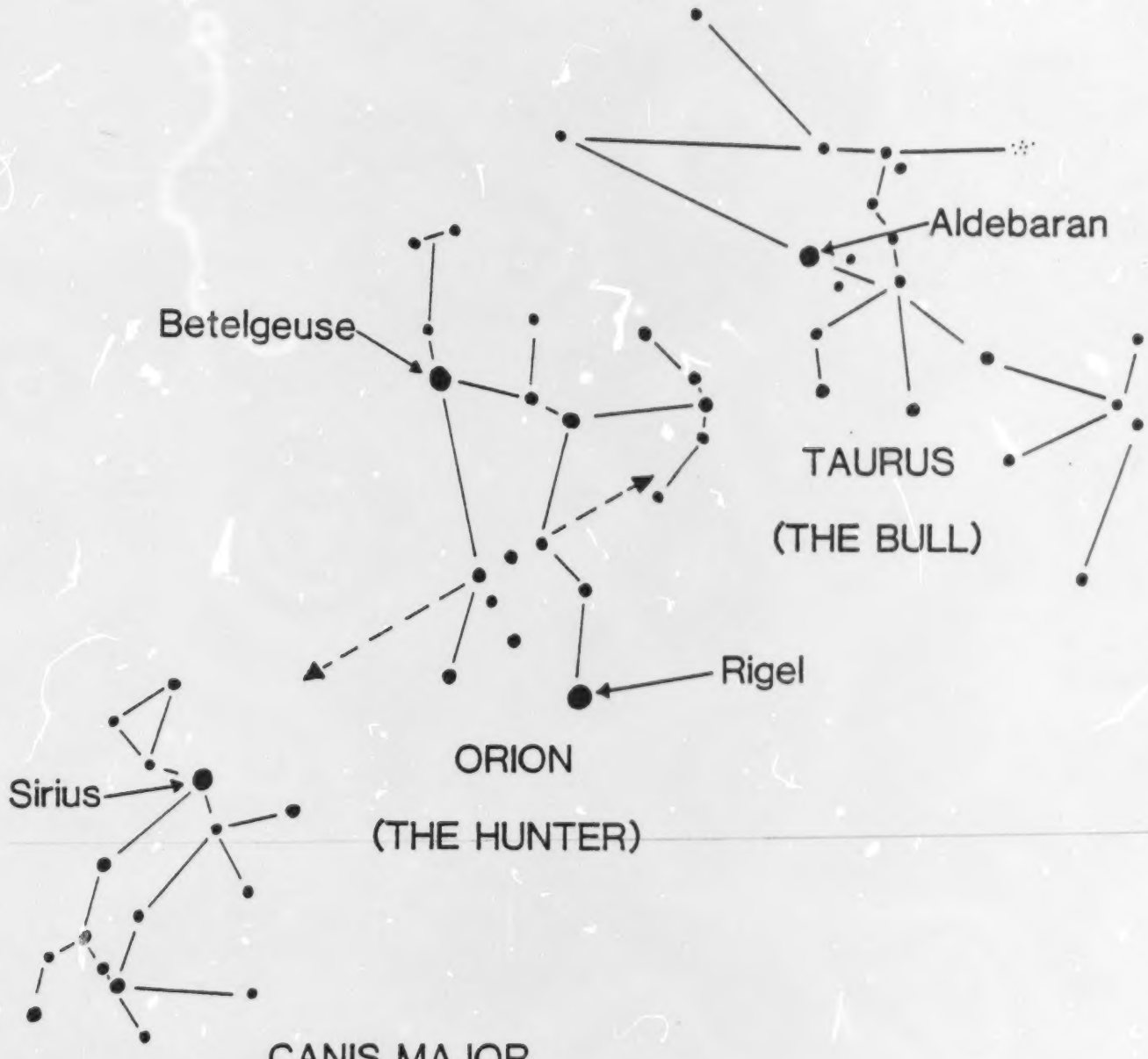
FINDING THE NORTHERN CROWN



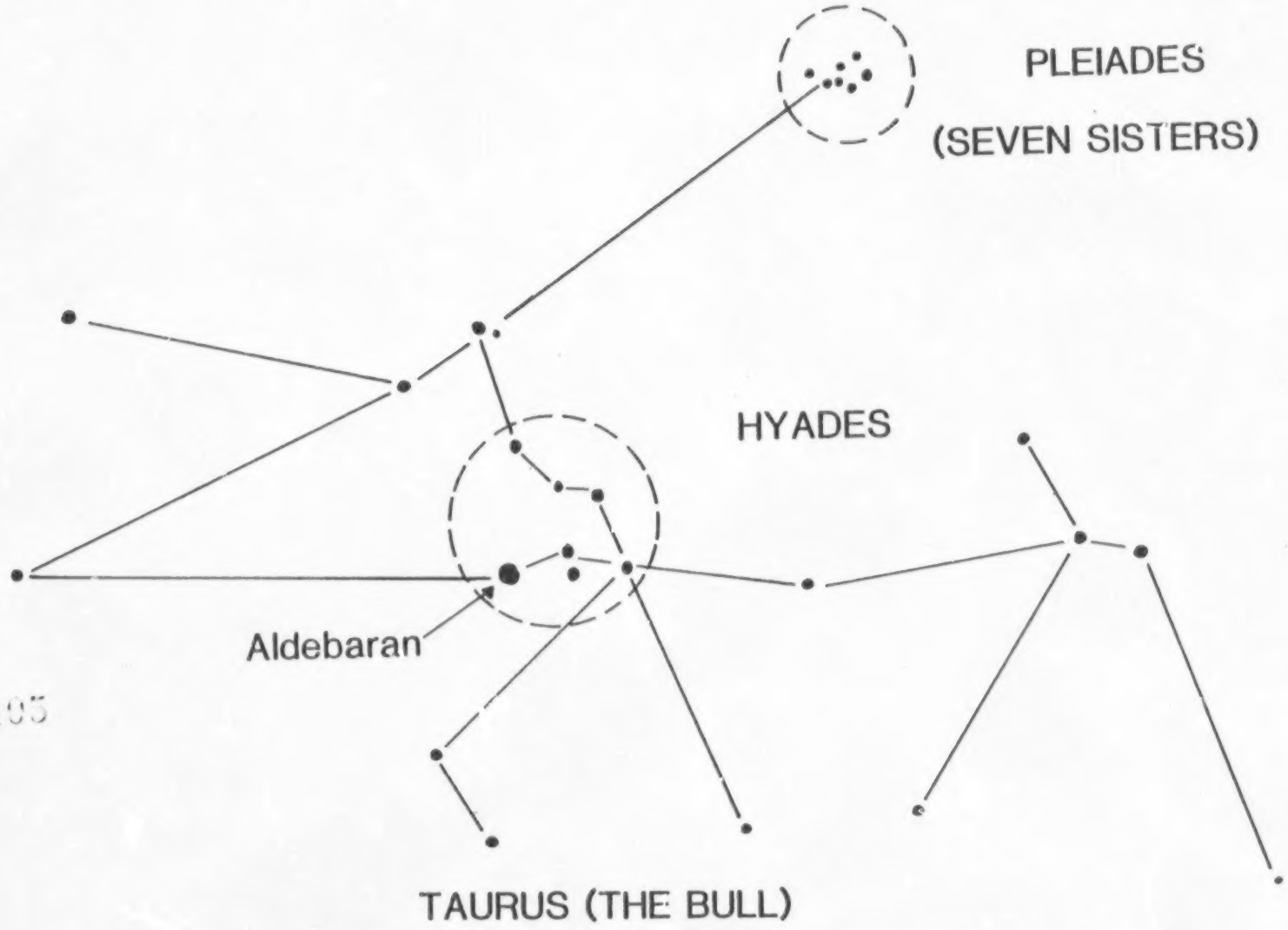
FINDING BOOTES, SCORPIUS & VIRGO



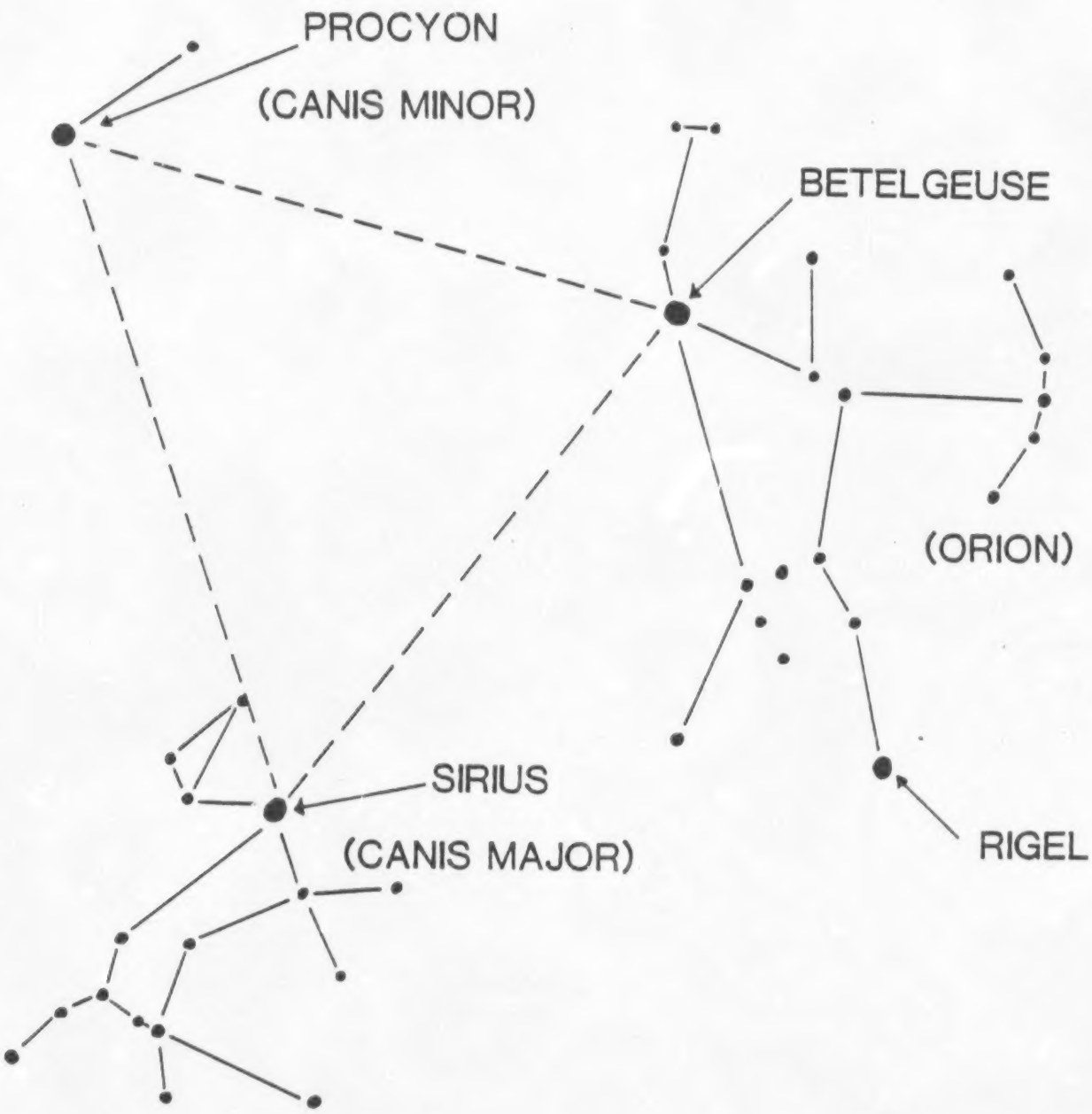
CANIS MAJOR, ORION & TAURUS



THE PLEIADES & HYADES



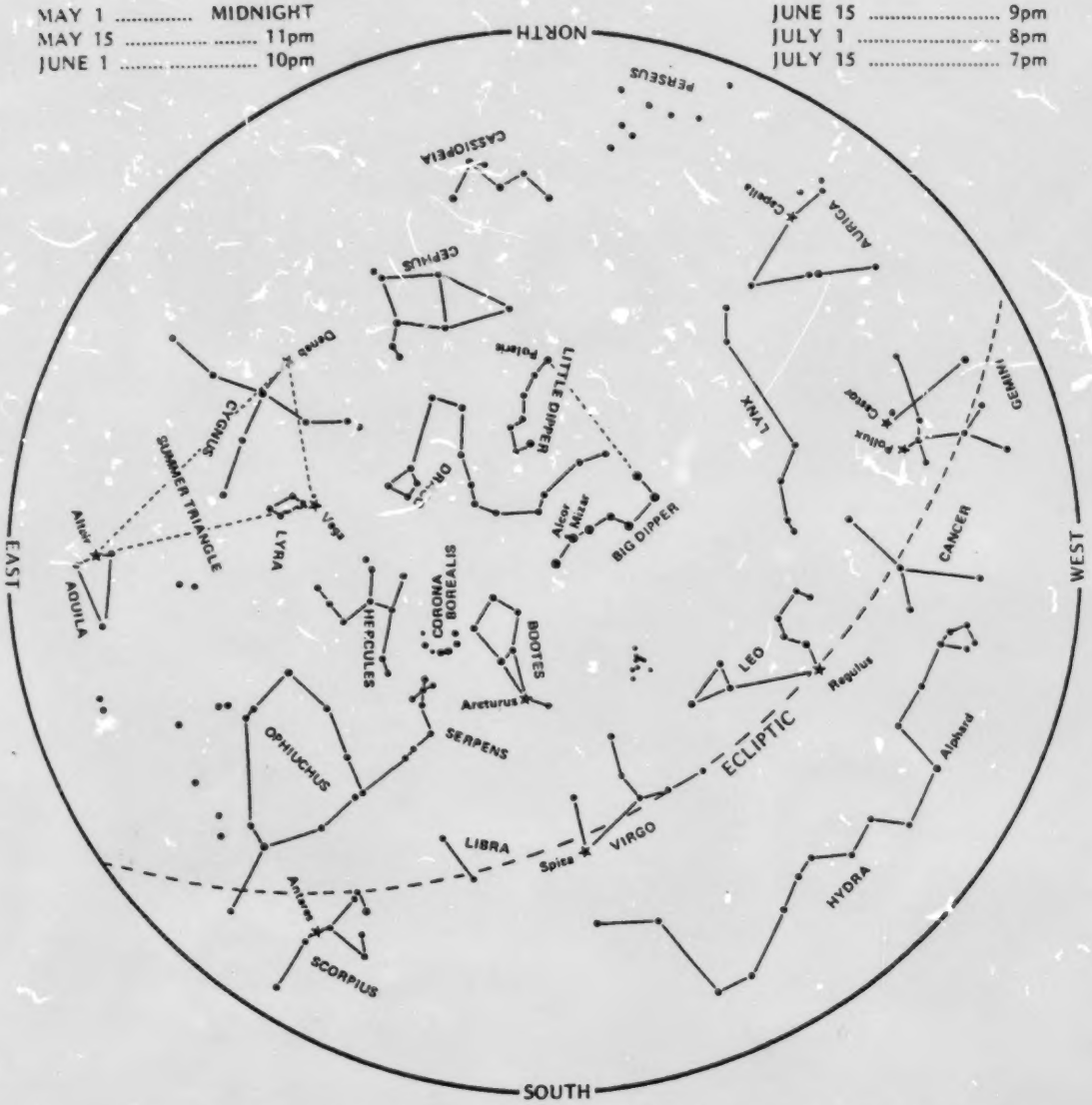
THE BIG TRIANGLE



SPRING STARS

THIS STAR MAP WILL WORK BEST AT THESE TIMES:

MAY 1 ..... MIDNIGHT
MAY 15 ..... 11pm
JUNE 1 ..... 10pm
JUNE 15 ..... 9pm
JULY 1 ..... 8pm
JULY 15 ..... 7pm



Hold the map overhead and turn it so that the directions marked around the map's horizons match the true directions. Try and find the brightest stars and constellations first, then the fainter ones. If any planets are visible they will look like bright stars. Planets are always found close to the ecliptic.

The objects marked like ✸M13 are objects such as galaxies, nebulae or star clusters. Under a dark country sky most of these can be observed with the eye alone. They are best observed with binoculars or a telescope.

For more information about sky watching, consult *The Sky Observers Guide* by Mayall, Mayall, and Wyckoff, The Golden Press, New York, 1965. A star map that will work all year, at any hour, is *Philip's Planisphere.* These and other helpful publications are available at the Museum Bookstore.

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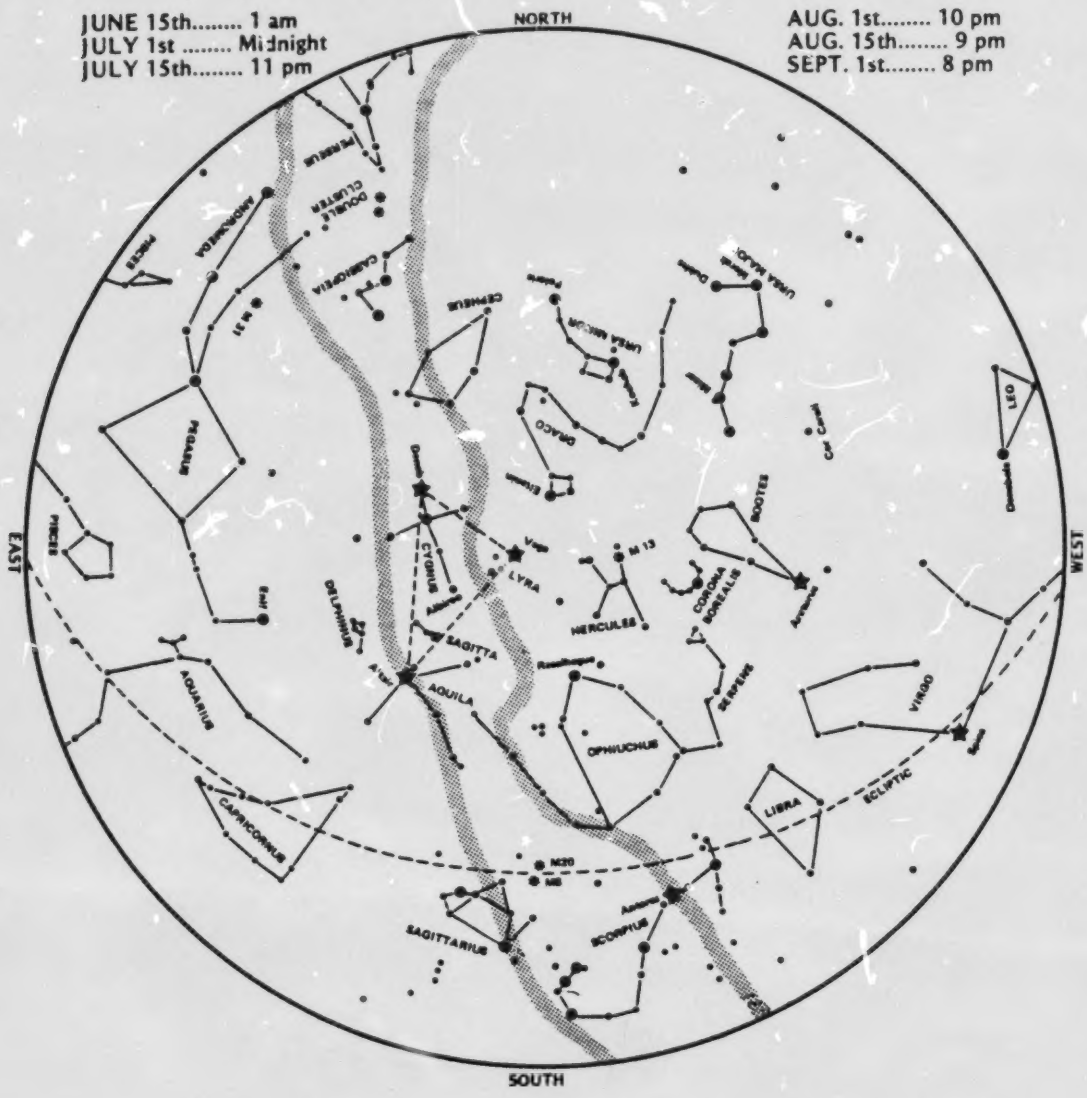
SUMMER STARS

This star map will work best at these times:

JUNE 15th..... 1 am
JULY 1st ..... Midnight
JULY 15th..... 11 pm

AUG. 1st..... 10 pm
AUG. 15th..... 9 pm
SEPT. 1st..... 8 pm



Hold the map overhead and turn it so that the directions marked around the map's horizons match the true directions. Try and find the brightest stars and constellations first, then the fainter ones. If any planets are visible they will look like bright stars. Planets are always found close to the ecliptic.

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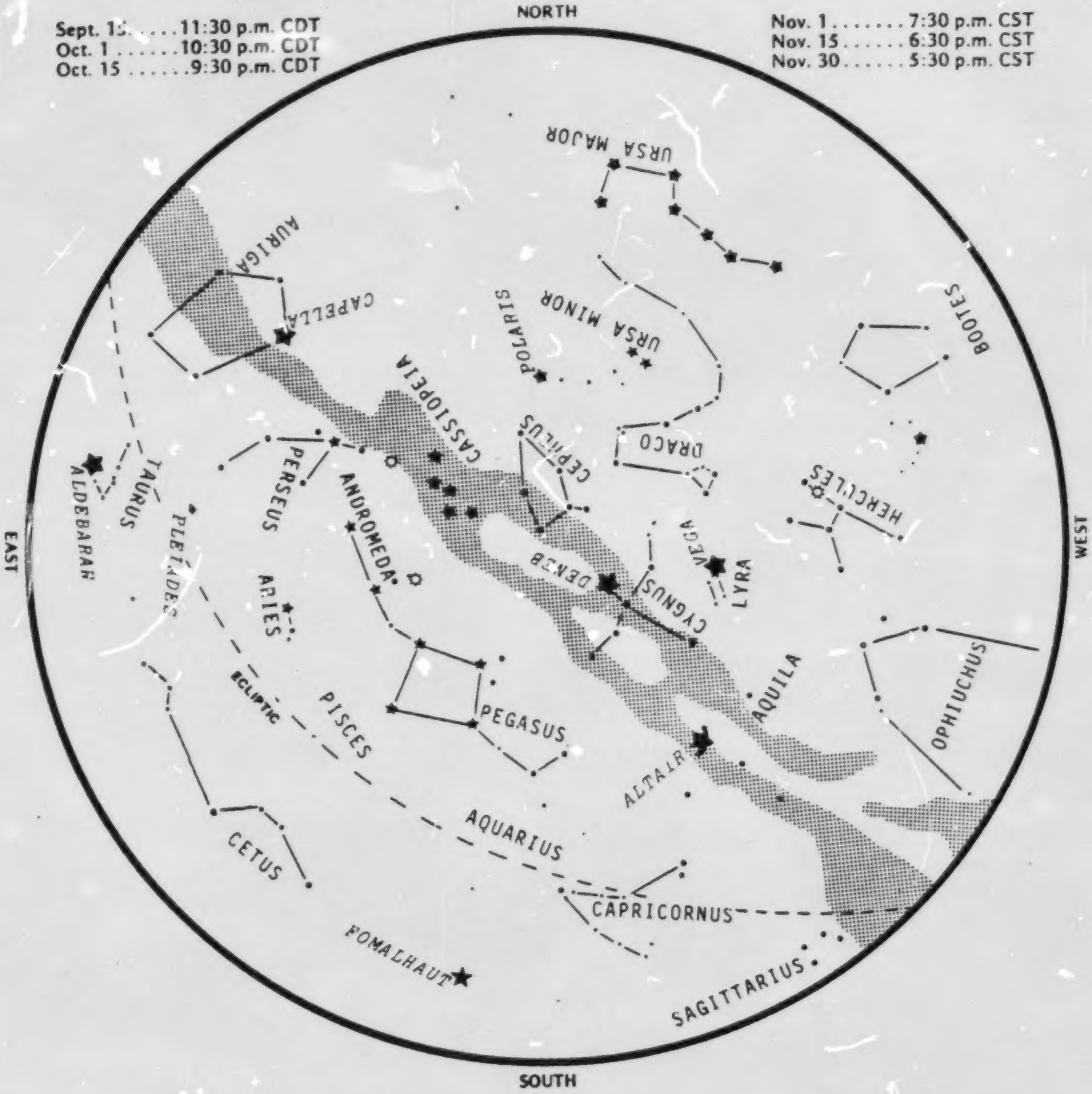
AUTUMN STARS

THIS STAR MAP WILL WORK BEST AT THESE TIMES:

Sept. 15 . . . . 11:30 p.m. CDT
Oct. 1 . . . . . 10:30 p.m. CDT
Oct. 15 . . . . . 9:30 p.m. CDT

Nov. 1 . . . . . 7:30 p.m. CST
Nov. 15 . . . . . 6:30 p.m. CST
Nov. 30 . . . . . 5:30 p.m. CST



Hold the map overhead and turn it so that the directions marked around the map's horizons match the true directions. Try and find the brightest stars and constellations first, then the fainter ones. If any planets are visible they will look like bright stars. Planets are always found close to the ecliptic.

The objects marked like ✸M13 are objects such as galaxies, nebulae or star clusters. Under a dark country sky most of these can be observed with the eye alone. They are best observed with binoculars or a telescope.

For more information about sky watching, consult *The Sky Observers Guide* by Mayall, Mayall, and Wyckoff, The Golden Press, New York, 1965. A star map that will work all year, at any hour, is *Philip's Planisphere.* These and other helpful publications are available at the Museum Bookstore.

MANITOBA PLANETARIUM

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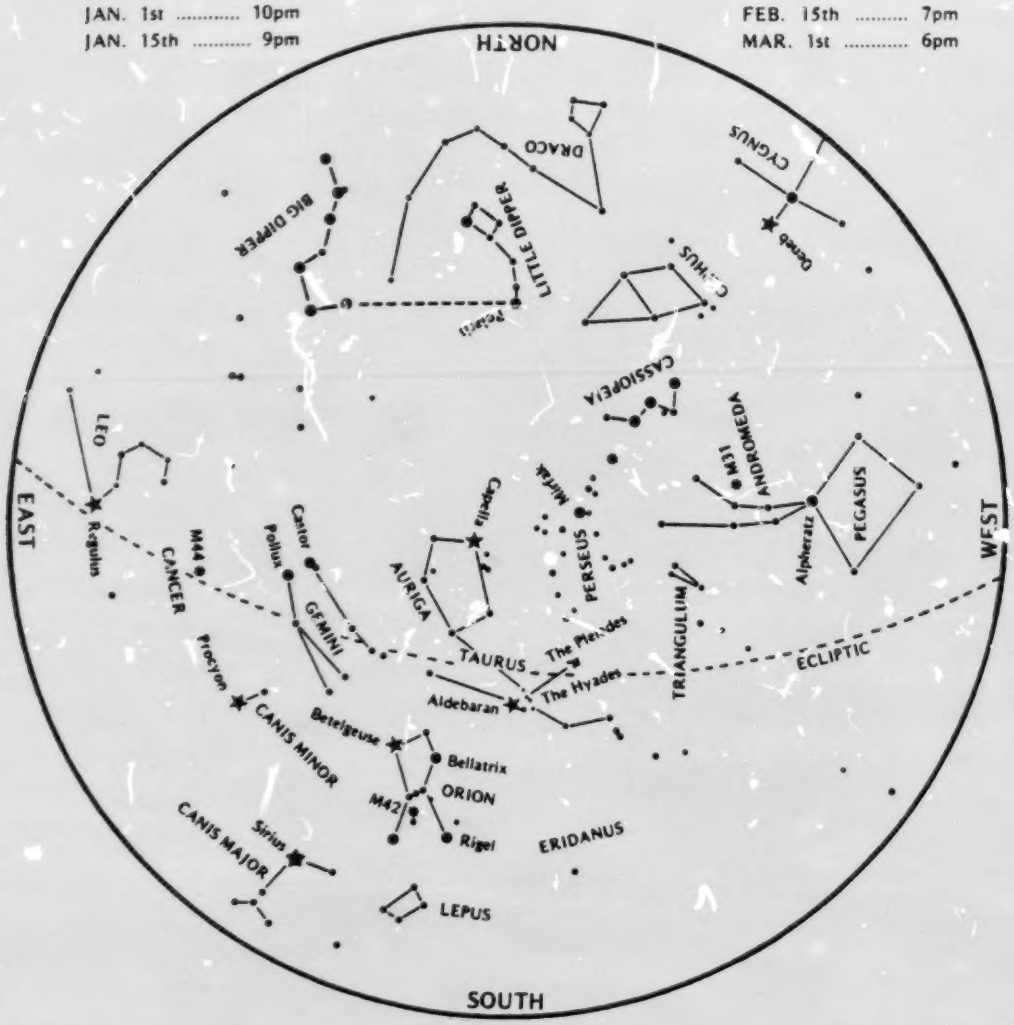
WINTER STARS

THIS STAR MAP WILL WORK BEST AT THESE TIMES:

DEC. 15th 11pm
JAN. 1st 10pm
JAN. 15th 9pm
FEB. 1st 8pm
FEB. 15th 7pm
MAR. 1st 6pm



Hold the map overhead and turn it so that the directions marked around the map's horizons match the true directions. Try and find the brightest stars and constellations first, then the fainter ones. If any planets are visible they will look like bright stars. Planets are always found close to the ecliptic.

The objects marked like ✸M13 are objects such as galaxies, nebulae or star clusters. Under a dark country sky most of these can be observed with the eye alone. They are best observed with binoculars or a telescope.

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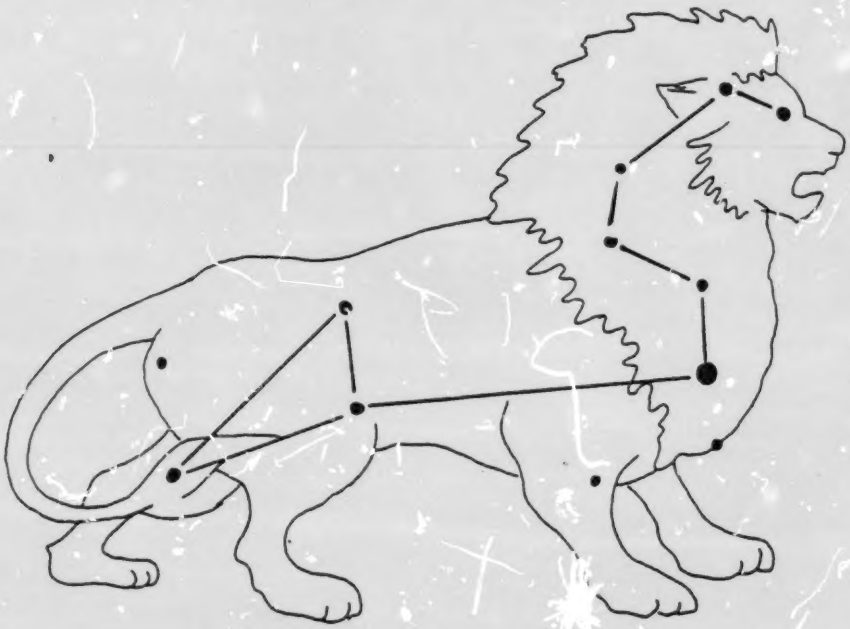
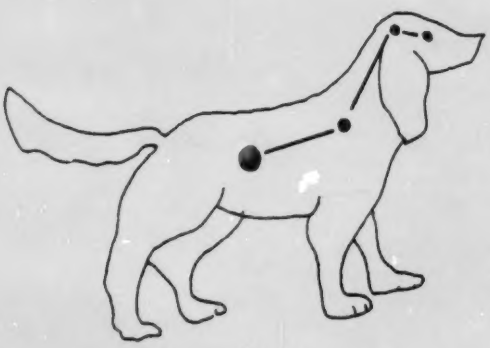
CONSTELLATIONS

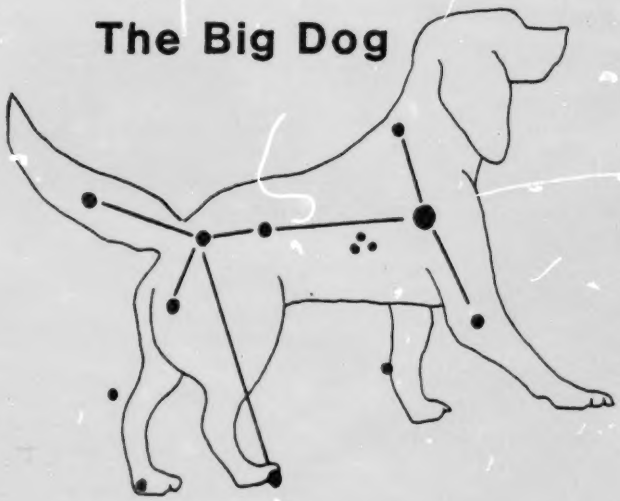
Leo, the Lion



Canis Minor, The Little Dog

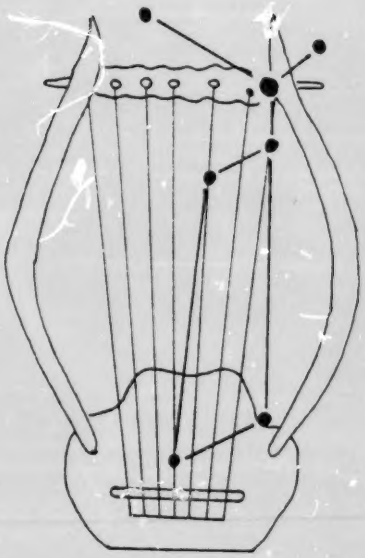


Canis Major , The Big Dog

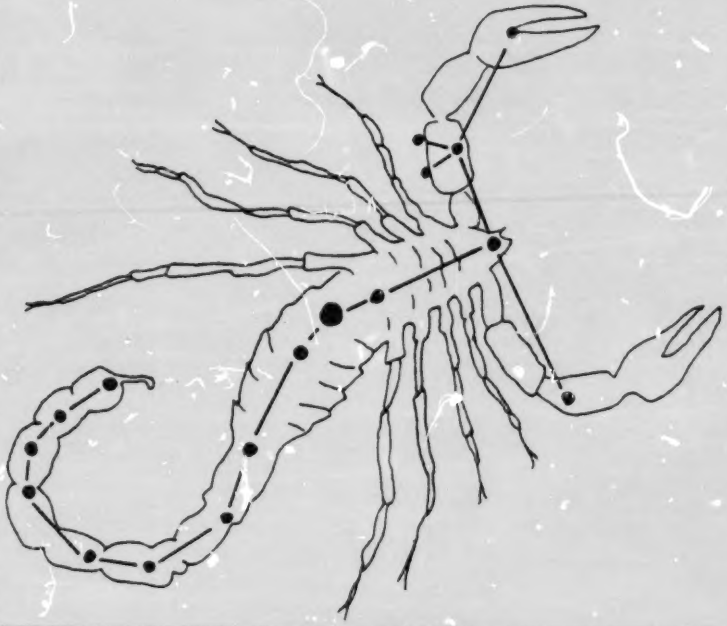


Corona, the Northern Crown

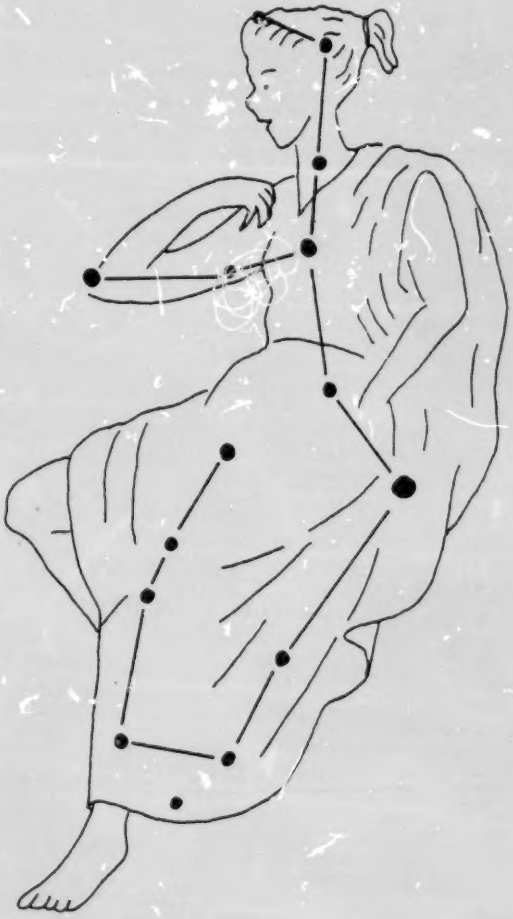
Lyra, the Lyre



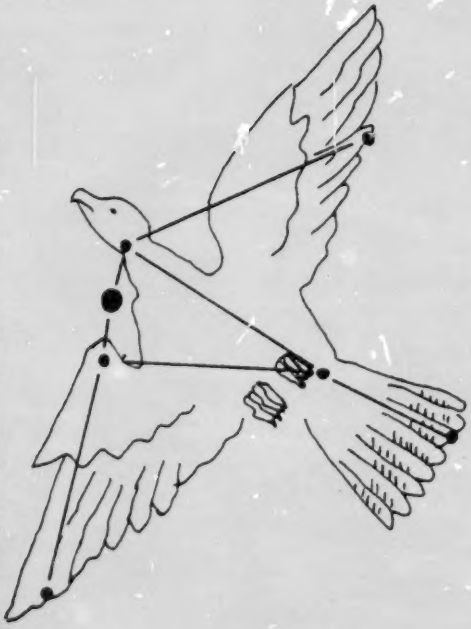
Scorpius, the Scorpion



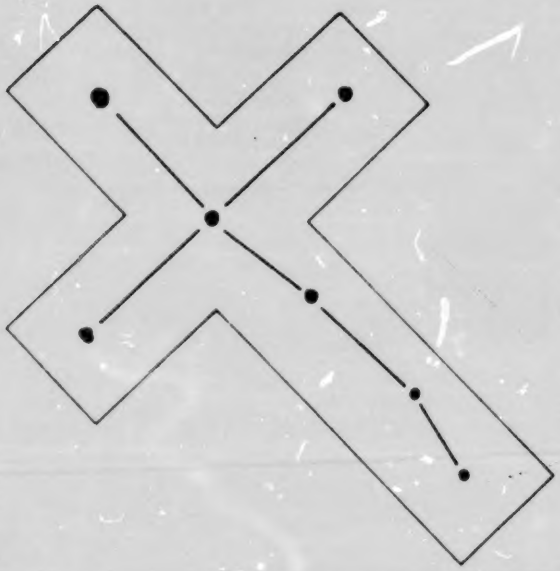
Virgo, the Maiden



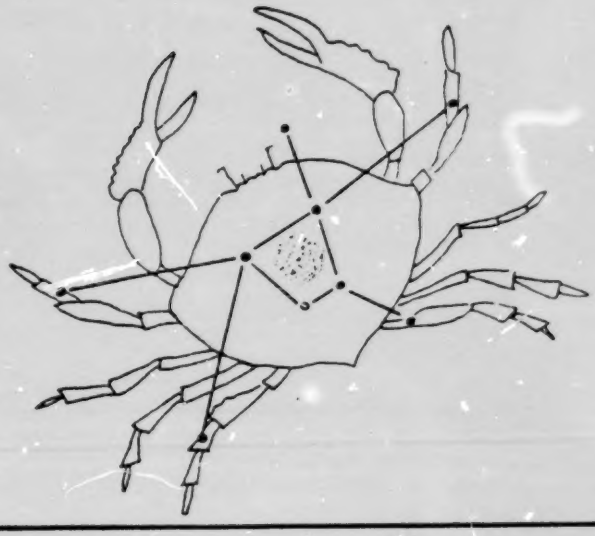
Aquila, the Eagle



The Northern Cross

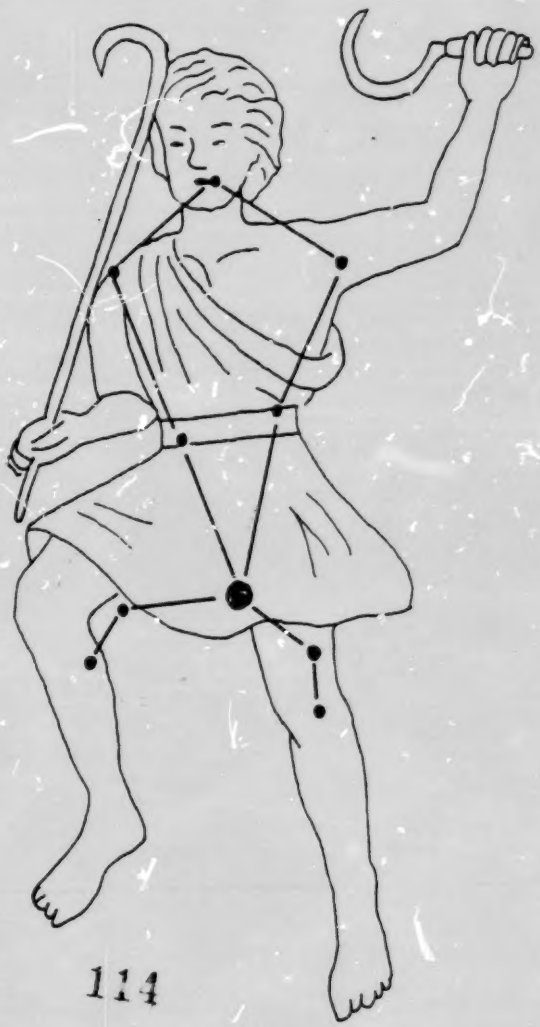


Cancer, the Crab



Orion, the Hunter

Bootes, the Herdsman

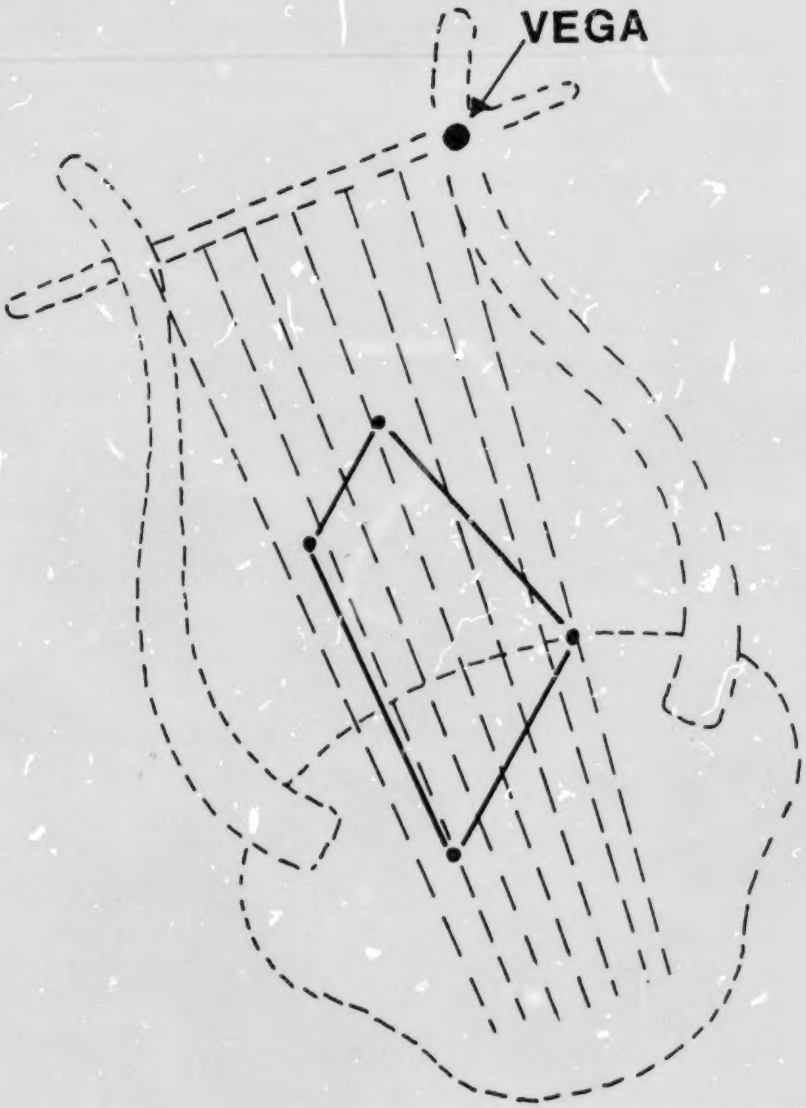


Hercules

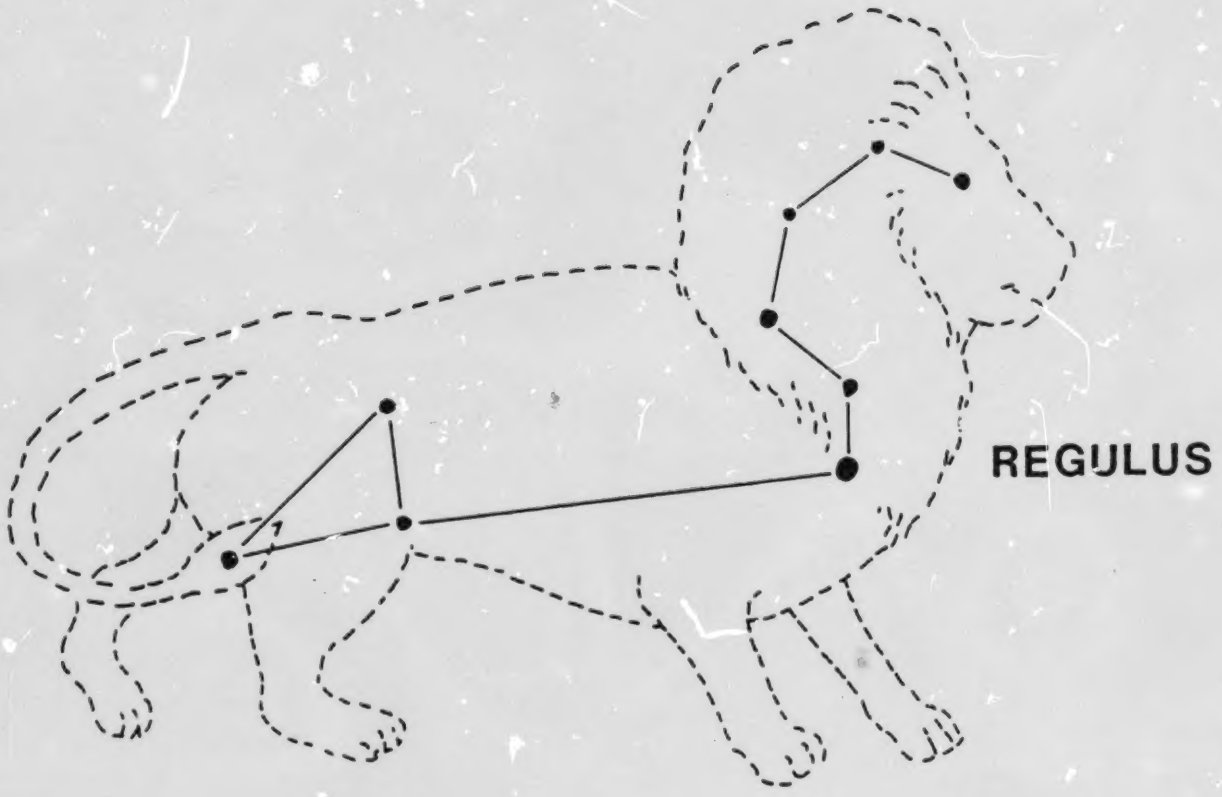
Cygnus, the Swan

Gemini, the Twins

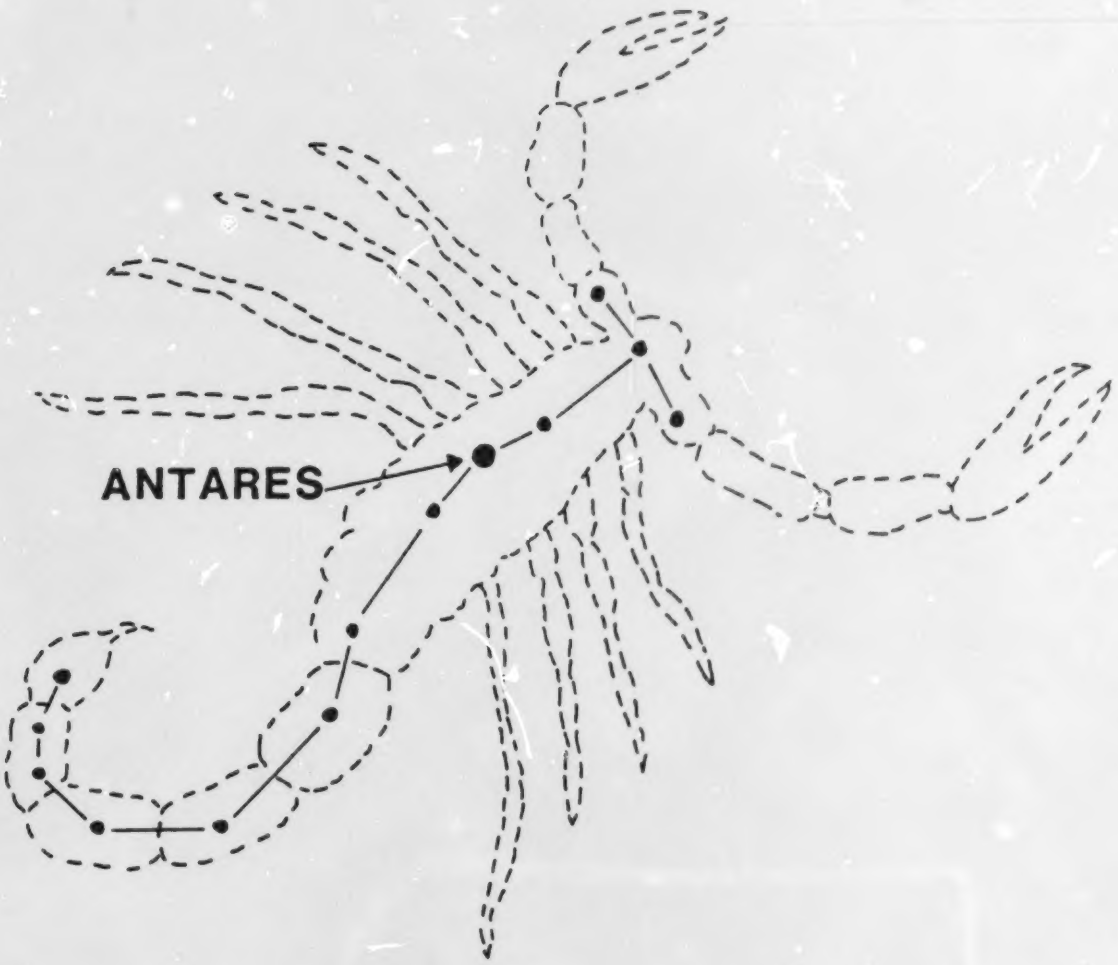
LYRA, THE LYRE



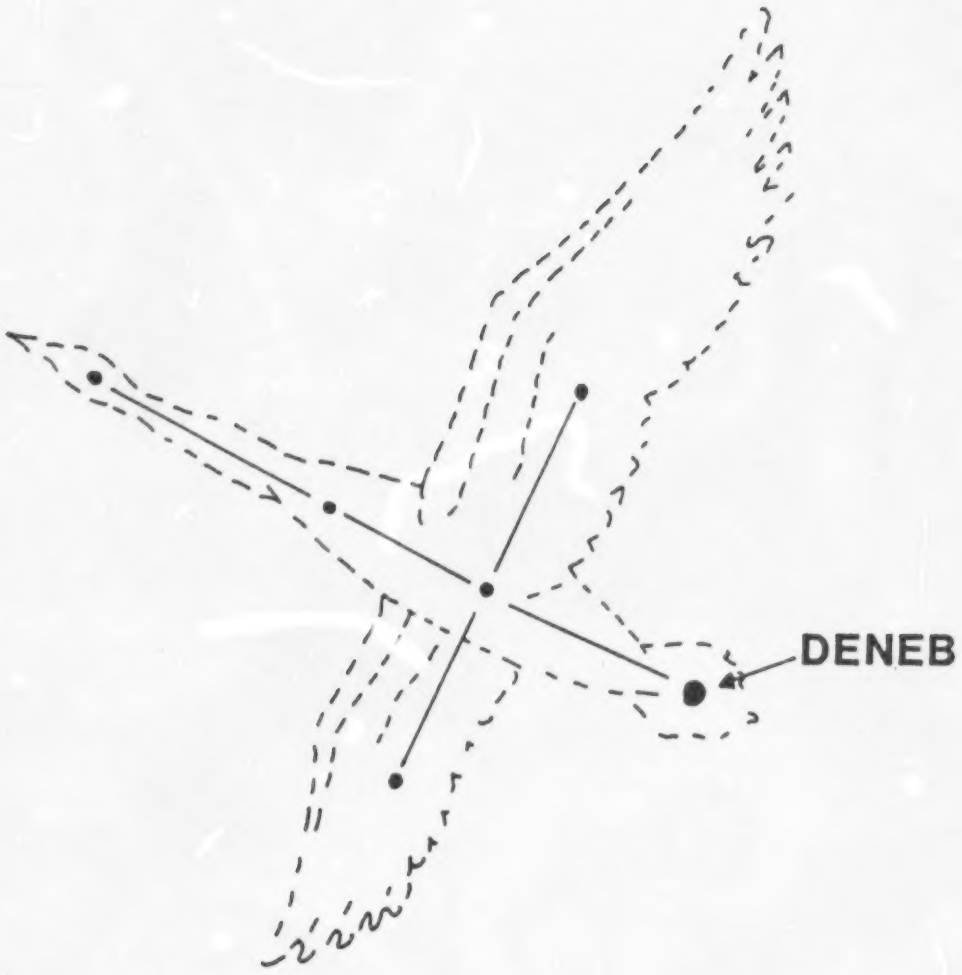
LEO, THE LION



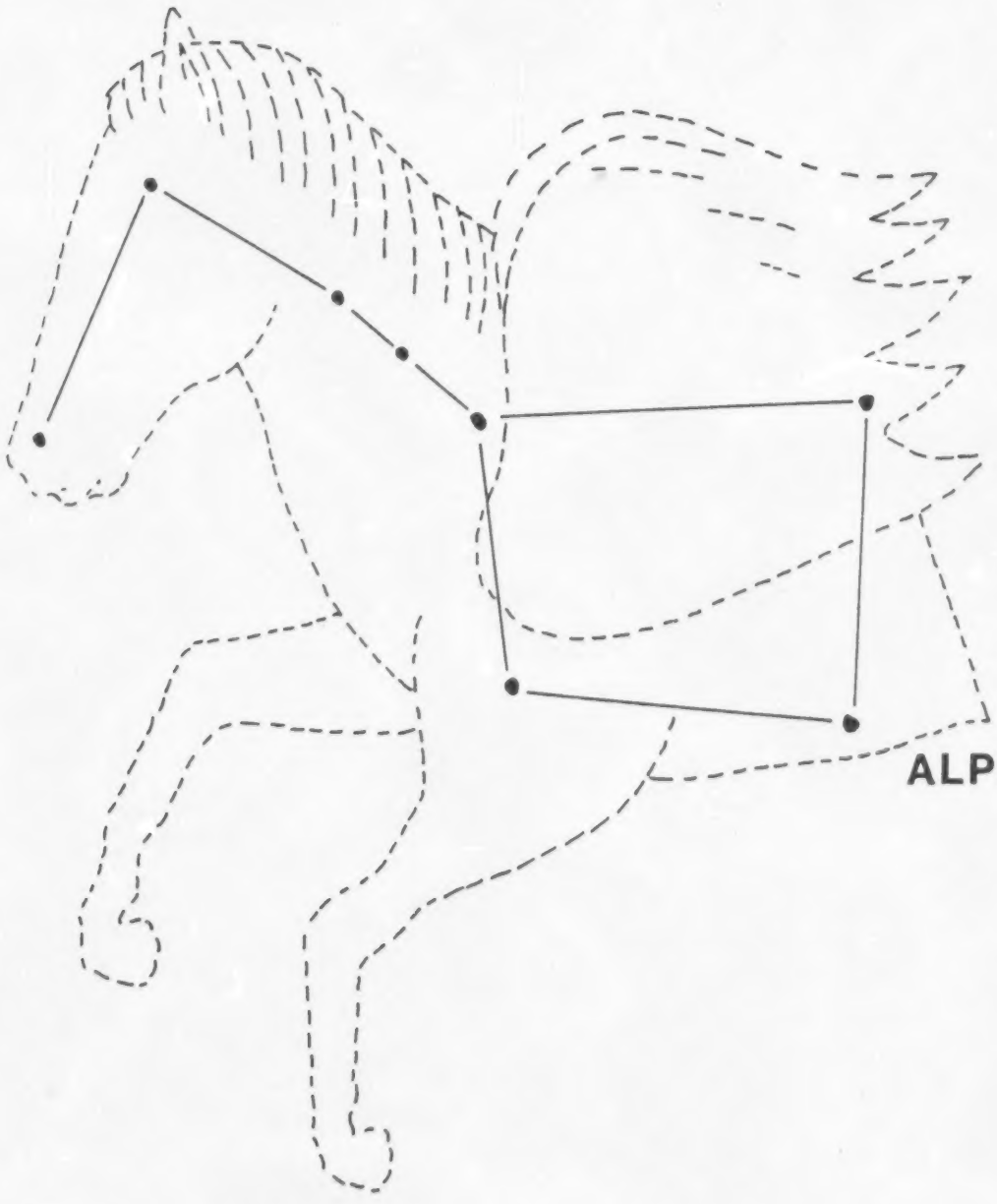
SCORPIUS, THE SCORPION



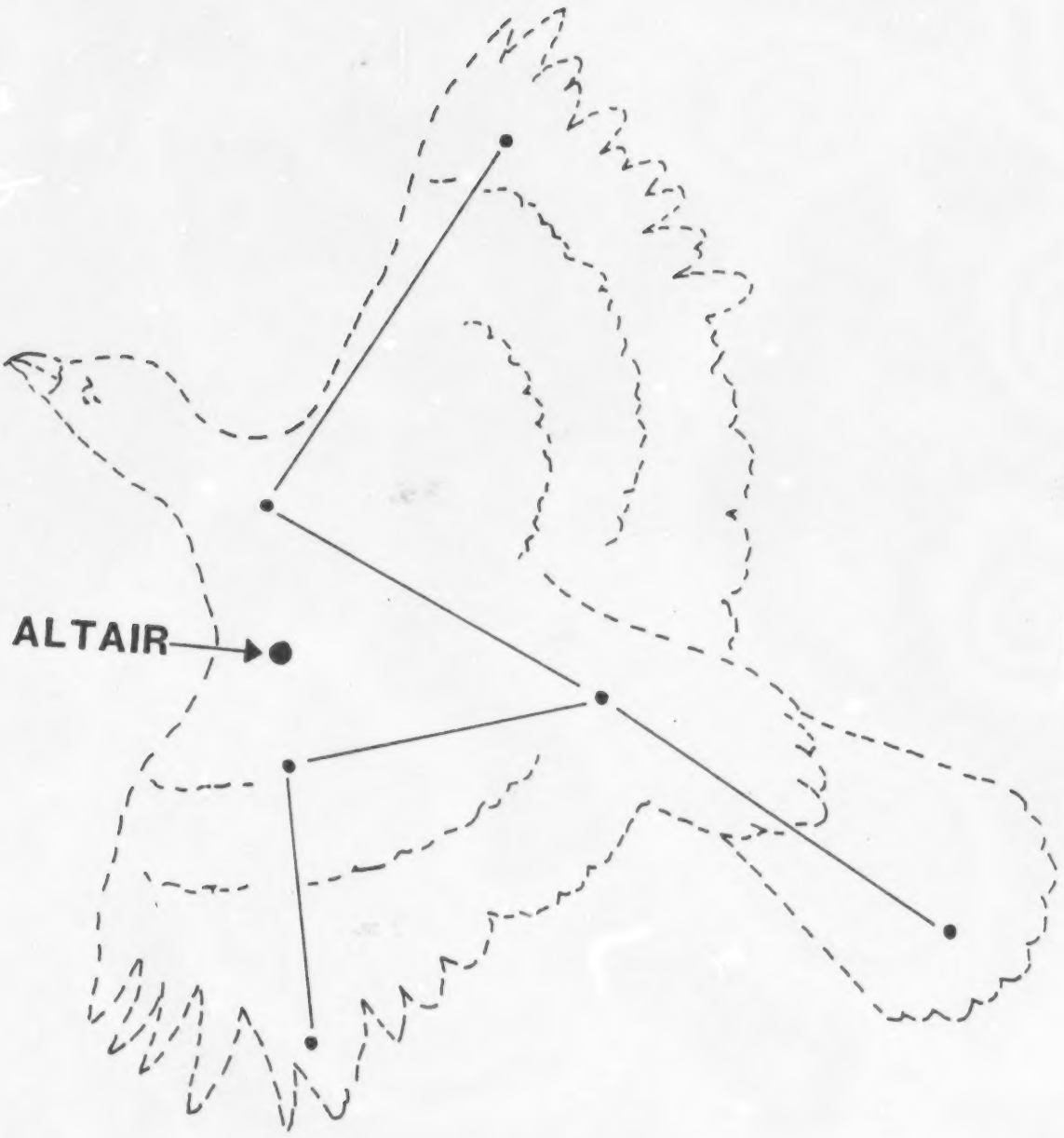
CYGNUS, THE SWAN



PEGASUS, THE WINGED HORSE



AQUILA, THE EAGLE



Observing the Sun. The sun provides an unending source of interest for the amateur with a small telescope. But *be careful*! Never look directly at the sun with the unaided eye or with any unfiltered optical instrument. Even filters can be unreliable. Eyepiece filters are extremely hazardous, and are not recommended. Herschel wedges or prisms, in conjunction with eyepiece filters, are acceptable in some cases, but potentially dangerous in others. Full-aperture filters on glass or Mylar are generally regarded as safest, if they are of good quality and are carefully maintained. These filters are placed on the front of the telescope, and reflect away most sunlight *before* it enters the telescope tube.

An alternate approach is to view the sun's image by projecting it onto a screen. This, however, has its dangers: unsupervised bystanders may try to look through the eyepiece; heat may build up inside the telescope and cause permanent damage.

There are many rewarding activities for the careful observer of the sun: counting sunspots, watching, drawing or photographing spots and spot groups, studying solar prominences with a narrow-band filter, or watching for rare "white-light flares" in the vicinity of sunspots.

For more information, see "Exploring the Sun from your Backyard" by Rodger Gordon, *Star and Sky*, 2, 21 (July, 1980). Serious observers of the sun should join the Solar Division of the American Association of Variable Star Observers, 187 Concord Ave., Cambridge, MA 02138, U.S.A.

The Sun—During June, the sun's R.A. increases from 4 h 35 m to 6 h 39 m and its Decl. changes from +22°01′ to +23°08′. The equation of time changes from +2 m 14 s to −3 m 35 s. The sun reaches the summer solstice on June 21, 06 h 45 m E.S.T., and summer begins in the northern hemisphere.

The Moon—On June 1.0 E.S.T., the age of the moon is 27.6 d. The sun's selenographic colongitude is 252.4° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on June 7 (7°) and minimum (east limb exposed) on June 22 (6°). The libration in latitude is maximum (north limb exposed) on June 27 (7°) and minimum (south limb exposed) on June 13 (7°).

Mercury on the 1st is in R.A. 6 h 11 m, Decl. +24°40′, and on the 15th is in R.A. 6 h 18 m, Decl. +21°08′. At the beginning of the month, it is well-placed, standing about 16° above the western horizon at sunset. By June 21, it is in inferior conjunction, and is not visible for the rest of the month. On June 9, it is 1.7° south of Venus.

Venus on the 1st is in R.A. 5 h 37 m, Decl. +24°03′, and on the 15th it is in R.A. 6 h 52 m, Decl. +24°05′, mag. −3.3, and transits at 13 h 20 m. Throughout the month, it can be seen low in the west just after sunset. On June 9, it is 1.7° north of Mercury. By month's end, it makes a striking pattern with Castor and Pollux. See also "Jupiter" below.

Mars on the 15th is in R.A. 4 h 20 m, Decl. +21°35′, mag. +1.7, and transits at 10 h 47 m. As it gradually moves away from the sun, it becomes more conspicuous in the eastern sky just before sunrise. In Taurus, it passes between the Hyades and Pleiades around June 10, and 6° north of Aldebaran on June 19.

Jupiter on the 15th is in R.A. 12 h 06 m, Decl. +0°52′, mag. −1.7, and transits at 18 h 29 m. In Virgo a few degrees west of Saturn, it is slightly west of the meridian at sunset, and sets about 5 hours later. By the end of the month, Venus, Regulus, Jupiter, Saturn and Spica form a striking configuration across the evening sky.

Saturn on the 15th is in R.A. 12 h 15 m, Decl. +1°02′, mag. +1.1, and transits at 18 h 39 m. In Virgo a few degrees east of Jupiter, it is slightly west of the meridian at sunset, and sets about 5 hours later. See also "Jupiter" above.

Uranus on the 15th is in R.A. 15 h 39 m, Decl. −19°17′, mag. +5.8, and transits at 22 h 02 m. On June 25–26, it passes about 2′ N of 41 Lib.

Neptune on the 15th is in R.A. 17 h 32 m, Decl. −21°55′, mag. +7.7, and transits at 23 h 54 m. It is at opposition on June 14, 11 h.

1981	d	h	m	JUNE E.S.T.	Min. of Algol h	m	Configuration of Jupiter's Satellites (Date Markers are U.T.)
Mon.	1	09		Moon at perigee (358,483 km)			
Tues.	2	06	32	●New Moon	16	20	
Wed.	3			Mars at ascending node			
		08		Venus 4° N. of Moon			
		18		Mercury 3° N. of Moon			
Thur.	4						
Fri.	5			Occultation by (129) Antigone, pg. 56–7	13	10	
		21		Saturn stationary			
Sat.	6			Mercury at descending node			
Sun.	7						
Mon.	8				10	00	
Tues.	9	03		Mercury stationary			
		06		Mercury 1.7 S. of Venus			
		06	33	◗ First Quarter			
Wed.	10	04		Jupiter 3° S. of Moon			
		09		Saturn 2° S. of Moon			
Thur.	11				6	50	
Fri.	12						
Sat.	13	22		Moon at apogee (405,798 km)			
Sun.	14	11		Neptune at opposition	3	30	
		21		Uranus 5° S. of Moon			
Mon.	15						
Tues.	16						
Wed.	17			Mercury at aphelion	0	20	
				Venus at perihelion			
		04		Neptune 1.9 S. of Moon			
		08		Juno stationary			
		10	04	○ Full Moon			
Thur.	18						
Fri.	19	15		Mars 6° N. of Aldebaran	21	10	
Sat.	20						
Sun.	21	06	45	Summer Solstice. Summer begins.			
		20		Mercury in inferior conjunction			
Mon.	22				18	00	
Tues.	23						
Wed.	24	15		Venus 5° S. of Pollux			
		23	25	◖ Last Quarter			
Thur.	25				14	50	
Fri.	26						
Sat.	27						
Sun.	28				11	40	
Mon.	29	14		Moon at perigee (362,350 km)			
Tues.	30	01		Mars 4° N. of Moon			

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THE SKY FOR JULY 1981

Early this month the earth is in aphelion; early in January it was at perihelion. The difference in distance from earth to sun between these two extremes is about 5,000,000 km or 3.3 per cent, which makes a difference in radiant heat received by the earth of nearly 7 per cent. Thus for the northern hemisphere the difference tends to warm our winters and cool our summers. However, the preponderance of large land masses in the northern hemisphere works the other way and tends to make our winters colder and summers hotter than those of the southern hemisphere. [by John F. Heard, reprinted from the 1976 HANDBOOK—*Ed.*]

The Sun—During July, the sun's R.A. increases from 6 h 39 m to 8 h 44 m and its Decl. changes from +23°08′ to +18°06′. The equation of time changes from −3 m 47 s to −6 m 17 s. The earth is at aphelion on July 3 at a distance of 152,103,500 km (94,513,000 mi) from the sun. There is a total eclipse of the sun on July 31.

The Moon—On July 1.0 E.S.T., the age of the moon is 28.3 d. The sun's selenographic colongitude is 259.1° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on July 5 (6°) and minimum (east limb exposed) on July 19 (5°). The libration in latitude is maximum (north limb exposed) on July 24 (7°) and minimum (south limb exposed) on July 10 (7°). There is a partial eclipse of the moon on the night of July 16–17, visible in North America.

Mercury on the 1st is in R.A. 5 h 46 m, Decl. +18°44′, and on the 15th is in R.A. 6 h 08 m, Decl. +20°50′. Throughout the month, it is very low in the east just before sunrise. Greatest elongation west (21°) is on July 14, but this is not a particularly favourable elongation for several reasons: the greatest elongation is less than average, the planet is south of the ecliptic, and the ecliptic is not steeply inclined to the horizon.

Venus on the 1st is in R.A. 8 h 16 m, Decl. +21°21′, and on the 15th it is in R.A. 9 h 25 m, Decl. +16°52′, mag. −3.3, and transits at 13 h 55 m. It can be seen low in the west just after sunset. Moving from Cancer into Leo, it passes through the Praesepe Cluster around July 5–6, and north of Regulus on July 23.

Mars on the 15th is in R.A. 5 h 50 m, Decl. +23°52′, mag. +1.7, and transits at 10 h 18 m. It rises about 2 hours before the sun, and is low in the east at sunrise. Moving from Taurus into Gemini, it makes a pretty picture with the Hyades, the Pleiades, and the several bright stars in this region.

Jupiter on the 15th is in R.A. 12 h 16 m, Decl. −0°19′, mag. −1.5, and transits at 16 h 41 m. In Virgo, it is in the south-west at sunset, and sets about 3 hours later. At the beginning of the month, it is about 2° west of Saturn, but by July 30, it passes 1.2° south of Saturn, moving in direct motion. On July 21–22, it passes close to η Vir.

Saturn on the 15th is in R.A. 12 h 20 m, Decl. +0°27′, mag. +1.2, and transits at 16 h 45 m. In Virgo, it is in the south-west at sunset, and sets about 3 hours later. See also "Jupiter" above.

Uranus on the 15th is in R.A. 15 h 36 m, Decl. −19°06′, mag. +5.8, and transits at 20 h 01 m.

Neptune on the 15th is in R.A. 17 h 29 m, Decl. −21°53′, mag. +7.7, and transits at 21 h 53 m.

1981				JULY E.S.T.	Min. of Algol	Configuration of Jupiter's Satellites (Date Markers are U.T.)
	d	h	m		h m	
Wed.	1	14	03	● New Moon	8 30	
Thur.	2					
Fri.	3	08		Venus 1.3 N. of Moon		
		09		Mercury stationary		
		18		Earth at aphelion		
Sat.	4				5 20	
Sun.	5					
Mon.	6					
Tues.	7			Mercury at greatest hel. lat. S.	2 00	
		15		Jupiter 4° S. of Moon		
		18		Saturn 2° S. of Moon		
Wed.	8			Venus at greatest hel. lat. N.		
		16		Pluto stationary		
		21	39	◗ First Quarter		
Thur.	9				22 50	
Fri.	10					
Sat.	11	13		Moon at apogee (404,838 km)		
Sun.	12	03		Uranus 5° S. of Moon	19 40	
Mon.	13					
Tues.	14	09		Mercury at greatest elong. W. (21°)		
		10		Neptune 2° S. of Moon		
Wed.	15				16 30	
Thur.	16	23	39	○ Full Moon. Eclipse of ☾, pg. 55		
Fri.	17					
Sat.	18				13 20	
Sun.	19					
Mon.	20					
Tues.	21	09		Pallas in conjunction with Sun	10 10	
Wed.	22					
Thur.	23	16		Venus 1.2 N. of Regulus		
Fri.	24	04	40	☾ Last Quarter	7 00	
Sat.	25					
Sun.	26			Mercury at ascending node		
Mon.	27	04		Moon at perigee (367,265 km)	3 40	
Tues.	28			Jupiter at aphelion		
		12		δ Aquarid Meteors		
		19		Mars 3° N. of Moon		
Wed.	29	14		Mercury 6° S. of Pollux		
Thur.	30	17		Jupiter 1°2 S. of Saturn	0 30	
		22	52	● New Moon. Eclipse of ☉, pg. 55.		
Fri.	31			Mercury at perihelion		

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THE SKY FOR AUGUST 1981

The Perseid meteor shower occurs on August 12, and for a few days around this date, meteors will be numerous, especially after midnight. The shower meteors will appear to radiate from the constellation Perseus, hence the name of the shower. Unfortunately the moon is close to full at this time, and will certainly reduce the visibility of the meteors.

The Perseids could still provide a pleasant surprise in 1981. Meteor showers are associated with comets. The meteoric particles are the gritty debris left behind when the volatile ices in the comet turn to vapour. The Perseid shower is associated with Comet 1862 III Swift-Tuttle, which was last seen in 1862. According to Brian G. Marsden (pg. 98), this comet will be making its first predicted return to perihelion on Sept. 16, 1981 (give or take two years). As Peter M. Millman therefore points out (pg. 99) "a better than average shower in August is a possibility".

The Sun—During August, the sun's R.A. increases from 8 h 44 m to 10 h 40 m and its Decl. changes from +18°06′ to +8°24′. The equation of time changes from −6 m 14 s to −0 m 13 s.

The Moon—On Aug. 1.0 E.S.T., the age of the moon is 0.6 d. The sun's selenographic colongitude is 278.0° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Aug. 2 (5°) and Aug. 29 (5°) and minimum (east limb exposed) on Aug. 15 (5°). The libration in latitude is maximum (north limb exposed) on Aug. 20 (7°) and minimum (south limb exposed) on Aug. 6 (7°).

Mercury on the 1st is in R.A. 8 h 03 m, Decl. +21°26′, and on the 15th is in R.A. 9 h 59 m, Decl. +14°07′. It is too close to the sun to be easily seen, being in superior conjunction on Aug. 10.

Venus on the 1st is in R.A. 10 h 44 m, Decl. +9°31′, and on the 15th it is in R.A. 11 h 46 m, Decl. +2°34′, mag. −3.4, and transits at 14 h 13 m. It is very low in the west just after sunset. Moving from Leo into Virgo, it passes 2° south of Saturn on Aug. 25, and 0.9° south of Jupiter on Aug. 27.

Mars on the 15th is in R.A. 7 h 20 m, Decl. +22°57′, mag. +1.8, and transits at 9 h 46 m. It rises about 2½ hours before the sun, and—thanks to the steep angle between the ecliptic and the horizon—it is well up in the east at sunrise. Watch its changing position relative to Castor and Pollux during the month. It passes 1.5° S. of ε Gem on Aug. 1–2, 3° N. of ζ Gem on Aug. 8–9, and 1° N. of δ Gem on Aug. 14.

Jupiter on the 15th is in R.A. 12 h 33 m, Decl. −2°18′, mag. −1.3, and transits at 14 h 57 m. In Virgo, it is very low in the south-west at sunset, and sets about 2 hours later. During the month, it gradually moves eastward away from the nearby Saturn. See also "Venus" above.

Saturn on the 15th is in R.A. 12 h 29 m, Decl. −0°38′, mag. +1.2, and transits at 14 h 52 m. In Virgo, it is very low in the south-west at sunset, and sets about 2 hours later. See also "Jupiter" and "Venus" above.

Uranus on the 15th is in R.A. 15 h 35 m, Decl. −19°05′, mag. +5.9, and transits at 17 h 58 m.

Neptune on the 15th is in R.A. 17 h 26 m, Decl. −21°53′, mag. +7.7, and transits at 19 h 49 m.

1981				AUGUST E.S.T.	Min. of Algol	Configuration of Jupiter's Satellites (Date Markers are U.T.)
	d	h	m		h m	
Sat.	1				21 20	
Sun.	2	08		Venus 2° S. of Moon		
Mon.	3					
Tues.	4	07		Jupiter 4° S. of Moon	18 10	
		07		Saturn 3° S. of Moon		
		08		Uranus stationary		
Wed.	5					
Thur.	6					
Fri.	7			Occultation by (18) Melpomene, pg. 56–7	15 00	
		14	26	☽ First Quarter		
Sat.	8	07		Moon at apogee (404,227 km)		
		10		Uranus 5° S. of Moon		
Sun.	9					
Mon.	10			Mercury at greatest hel. lat. N.	11 50	
		01		Mercury in superior conjunction		
		17		Neptune 2° S. of Moon		
Tues.	11					
Wed.	12	03		Perseid Meteors		
Thur.	13				8 40	
Fri.	14					
Sat.	15	11	37	○ Full Moon		
Sun.	16				5 20	
Mon.	17					
Tues.	18					
Wed.	19				2 10	
Thur.	20					
Fri.	21	16		Moon at perigee (369,652 km)	23 00	
Sat.	22	09	16	☾ Last Quarter		
Sun.	23	12		Mars 6° S. of Pollux		
Mon.	24				19 50	
Tues.	25	17		Venus 2° S. of Saturn		
Wed.	26	10		Mars 1.4 N. of Moon		
Thur.	27			Occultation by (105) Artemis, pg. 56-7	16 40	
		20		Venus 0.9 S. of Jupiter		
Fri.	28					
Sat.	29	09	43	● New Moon		
Sun.	30	18		Mercury 4° S. of Moon	13 30	
Mon.	31	20		Saturn 3° S. of Moon		

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THE SKY FOR SEPTEMBER 1981

Notice that the Harvest Moon occurs on September 13. By definition the Harvest Moon is the full moon nearest the autumnal equinox. Around this time, the moon provides an extra measure of light in the early evening, light that was (and is) useful for farmers gathering the harvest.

On the average, the moon rises 50 minutes later from one night to the next, because of its eastward motion around the sky. However, at autumnal equinox, the sun is moving southward at its maximum rate, and the full moon is therefore moving northward at its maximum rate. This northward motion partly counteracts the moon's tendency to rise later from night to night: as a result, the delay in rising may be as little as 20 minutes. Check the tables of moonrise to see that this is so.

Other "moons" have special but less-well-known names. According to Robert Burnham (*Astronomy*, June 1980, pg. 46), "January, for instance, is the Old Moon or the Moon after Yule. February's is the Wolf or the Hunger Moon. March has the Sap or Crow Moon, while April gets the Egg or Grass Moon. The Planting Moon comes in May, and the Rose or Flower Moon in June. July's is called the Thunder or Hay Moon. August has the Grain or Green Corn Moon, while September and October have the Harvest and Hunter's Moons, respectively. The year finishes off with the Frosty or Beaver Moon in November and the Long Night Moon in December."

The Sun—During September, the sun's R.A. increases from 10 h 40 m to 12 h 28 m and its Decl. changes from +8°24′ to −3°04′. The equation of time changes from +0 m 06 s to +10 m 05 s. The sun reaches the autumnal equinox on Sept. 22, 22 h 05 m E.S.T., and autumn begins in the northern hemisphere.

The Moon—On Sept. 1.0 E.S.T., the age of the moon is 2.2 d. The sun's selenographic colongitude is 296.7° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Sept. 24 (5°) and minimum (east limb exposed) on Sept. 11 (6°). The libration in latitude is maximum (north limb exposed) on Sept. 16 (7°) and minimum (south limb exposed) on Sept. 2 (7°) and Sept. 29 (7°).

Mercury on the 1st is in R.A. 11 h 49 m, Decl. +1°25′, and on the 15th is in R.A. 13 h 00m, Decl. −8°10′. Throughout the month, it can be seen with difficulty, low in the west at sunset. Greatest elongation east (26°) is on Sept. 23, but this is a classic unfavourable elongation for northern observers. It passes 4° south of Saturn on Sept. 10, 3° south of Jupiter on Sept. 13, and 0.4° south of Spica on Sept. 20.

Venus on the 1st is in R.A. 12 h 59 m, Decl. −6°11′, and on the 15th it is in R.A. 14 h 00m, Decl. −13°01′, mag. −3.5, and transits at 14 h 25 m. It is low in the south-west at sunset, and sets soon thereafter. Moving from Virgo into Libra, it passes 1.9° north of Spica on Sept. 6.

Mars on the 15th is in R.A. 8 h 43 m, Decl. +19°17′, mag. +1.8, and transits at 9 h 07 m. It rises about 4 hours before the sun, and is well up in the east at sunrise. Moving eastward through Cancer, it passes just north of the Praesepe Cluster around Sept. 13.

Jupiter on the 15th is in R.A. 12 h 55 m, Decl. −4°42′, mag. −1.2, and transits at 13 h 17 m. Early in the month, it can be seen very low in the south-west just after sunset, but by the end of the month, it is too low to be easily seen. It is 3° north of Mercury on Sept. 13.

Saturn on the 15th is in R.A. 12 h 41 m, Decl. −2°01′, mag. +1.1, and transits at 13 h 03 m. Early in the month, it can be seen very low in the south-west just after sunset, but by the end of the month, it is too low to be easily seen. It is 4° north of Mercury on Sept. 10.

Uranus on the 15th is in R.A. 15 h 38 m, Decl. −19°15′, mag. +5.9, and transits at 15 h 59 m. On Sept. 12–13, it passes very close to 41 Lib.

Neptune on the 15th is in R.A. 17 h 26 m, Decl. −21°54′, mag. +7.7, and transits at 17 h 47 m.

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1981	d	h	m	SEPTEMBER E.S.T.	Sun's Age	Configuration of Jupiter's Satellites (Date Markers are U.T.)
					h m	
Tues.	1	01		Jupiter 4° S. of Moon		
		08		Vesta 0.2 N. of Moon. Occ'n		
		10		Venus 5° S. of Moon		
Wed.	2			Mercury at descending node	10 20	
				Venus at descending node		
Thur.	3	08		Neptune stationary		
Fri.	4	19		Uranus 5° S. of Moon		
Sat.	5	02		Moon at apogee (404,448 km)	7 00	
Sun.	6	08	26	☽ First Quarter		
		16		Venus 1°.9 N. of Spica		
Mon.	7	01		Neptune 1°.9 S. of Moon		
Tues.	8				3 50	
Wed.	9					
Thur.	10	10		Mercury 4° S. of Saturn		
Fri.	11				0 40	
Sat.	12					
Sun.	13			Mercury at aphelion	21 30	
		14		Mercury 3° S. of Jupiter		
		22	09	☺ Full Moon, Harvest Moon		
Mon.	14					
Tues.	15	07		Ceres in conjunction with Sun		
Wed.	16	23		Moon at perigee (365,622 km)	18 20	
Thur.	17					
Fri.	18					
Sat.	19				15 10	
Sun.	20			Occultation by (14) Irene, pg. 56–7		
		14		Mercury 0.4 S. of Spica		
		14	47	☾ Last Quarter		
Mon.	21					
Tues.	22	22	05	Autumnal Equinox. Fall begins.	12 00	
Wed.	23	11		Mercury at greatest elong. E. (26°)		
Thur.	24	00		Mars 0.04 S. of Moon. Occ'n[1]		
Fri.	25				8 40	
Sat.	26					
Sun.	27	23	07	● New Moon		
Mon.	28				5 30	
Tues.	29	20		Vesta 0.4 S. of Moon. Occ'n		
		21		Mercury 9° S. of Moon		
Wed.	30					

[1]Visible in Central and N. Africa, S. Asia, Indonesia, N.W. Australia.

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THE SKY FOR OCTOBER 1981

Mars, which is moving into Leo, begins this month to rise about midnight and so commands the attention of the average sky gazer. It hasn't been very exciting this year, being between oppositions (the last one in February 1980, the next one in March 1982). On average the interval between oppositions is 780 days which is known as the synodic period. This is about 50 days longer than two years, so the oppositions work their way through the calendar at the average rate of 50 days per opposition and the position of Mars at opposition works its way around the ecliptic at a corresponding rate. When opposition occurs in August or September it is very favourable because Mars is then near its perihelion and so its distance to the earth is close. September 1968 was such an opposition, but the 1982 opposition will be rather poor and the February 25 1980 opposition was about as unfavourable as an opposition of Mars can be.

The Sun—During October, the sun's R.A. increases from 12 h 28 m to 14 h 24 m and its Decl. changes from −3°04′ to −14°20′. The equation of time changes from +10 m 24 s to +16 m 21 s.

The Moon—On Oct. 1.0 E.S.T., the age of the moon is 2.6 d. The sun's selenographic colongitude is 302.7° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Oct. 21 (7°) and minimum (east limb exposed) on Oct. 9 (7°). The libration in latitude is maximum (north limb exposed) on Oct. 13 (7°) and minimum (south limb exposed) on Oct. 27 (7°).

Mercury on the 1st is in R.A. 13 h 56 m, Decl. −15°29′, and on the 15th is in R.A. 13 h 45 m, Decl. −13°23′. For most of the month, it is too close to the sun to be easily seen, inferior conjunction being on Oct. 18. By the end of the month, however, it is well placed in the morning sky, above Jupiter and Spica, below Saturn, and about 17° above the south-eastern horizon at sunrise.

Venus on the 1st is in R.A. 15 h 12 m, Decl. −19°42′, and on the 15th it is in R.A. 16 h 18 m, Decl. −24°00′, mag. −3.8, and transits at 14 h 45 m. Throughout the month, it is in the south-west at sunset. It passes 2° south of Uranus on Oct. 7, 1.9° north of Antares on Oct. 17, and 5° south of Neptune on Oct. 29.

Mars on the 15th is in R.A. 9 h 57 m, Decl. +14°02′, mag. +1.7, and transits at 8 h 22 m. It rises about 5 hours before the sun, and is near the meridian at sunrise. Moving from Cancer into Leo, it passes 1.1° north of Regulus on Oct. 19.

Jupiter on the 15th is in R.A. 13 h 19 m, Decl. −7°10′, mag. −1.2, and transits at 11 h 43 m. Early in the month, it is too close to the sun to be seen, conjunction being on Oct. 14. By the end of the month, it can be seen very low in the east just before sunrise. See also "Mercury" above.

Saturn on the 15th is in R.A. 12 h 55 m, Decl. −3°27′, mag. +1.0, and transits at 11 h 19 m. Early in the month, it is too close to the sun to be seen, conjunction being on Oct. 5. By the end of the month, it can be seen low in the east just before sunrise. See also "Mercury" above.

Uranus on the 15th is in R.A. 15 h 44 m, Decl. −19°34′, mag. +6.0, and transits at 14 h 07 m. See also "Venus" above.

Neptune on the 15th is in R.A. 17 h 28 m, Decl. −21°57′, mag. +7.8, and transits at 15 h 51 m. See also "Venus" above.

1981				OCTOBER E.S.T.	Min of Algol	Configuration of Jupiter's Satellites (Date Markers are 0 h)
	d	h	m		h m	
Thur.	1	16		Venus 7′ S. of Moon	2 20	
Fri.	2	05		Uranus 4′ S. of Moon		
		20		Moon at apogee (405,333 km)		
Sat.	3			Mercury at greatest hel. lat. S.	23 10	
Sun.	4	09		Neptune 1.7 S. of Moon		
Mon.	5	23		Saturn in conjunction with Sun		
Tues.	6	02	45	☽ First Quarter	20 00	
		06		Mercury stationary		
Wed.	7			Occultation by (88) Thisbe, pg. 56–7		
				Venus at aphelion		
		06		Venus 2° S. of Uranus		
Thur.	8					
Fri.	9				16 50	
Sat.	10					
Sun.	11					
Mon.	12				13 40	
Tues.	13	07	49	○ Full Moon. Hunters' Moon		
Wed.	14	00		Jupiter in conjuction with Sun		
		21		Moon at perigee (360,481 km)		
Thur.	15				10 20	
Fri.	16					
Sat.	17	01		Venus 1.9 N. of Antares		
		13		Pluto in conjunction with Sun		
Sun.	18	06		Mercury in inferior conjunction	7 10	
Mon.	19	12		Mars 1.1 N. of Regulus		
		22	40	☾ Last Quarter		
Tues.	20					
Wed.	21	07		Orionid Meteors	4 00	
Thur.	22			Mercury at ascending node		
		12		Mars 1.4 S. of Moon		
Fri.	23					
Sat.	24				0 50	
Sun.	25	23		Saturn 3° S. of Moon		
Mon.	26	16		Mercury stationary	21 40	
Tues.	27			Mercury at perihelion		
		15	13	● New Moon		
Wed.	28					
Thur.	29			Venus at greatest hel. lat. S.	18 30	
		15		Uranus 4′ S. of Moon		
		20		Venus 5° S. of Neptune		
Fri.	30	11		Moon at apogee (406,288 km)		
Sat.	31	17		Neptune 1.4 S. of Moon		
		22		Venus 6° S. of Moon		

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THE SKY FOR NOVEMBER 1981

If you are a Venus watcher you may be puzzled to notice (or to read what we say about Venus this month) that although Venus is at greatest eastern elongation this month (on Nov. 10, E.S.T.), it is no higher in the south-western sky at sunset than it has been since mid-year. How can this be since Venus is moving away from the sun? (Want to think about it for a while?) Well, the answer lies mostly in the fact that the ecliptic (which *nearly* represents the path of motion of most planets) makes a much shallower angle with the horizon at early autumn sunset than at early summer sunset. This shallower angle more than makes up for the greater elongation of Venus from the sun.

This same phenomenon is also involved in the explanation of the Harvest Moon, and in the explanation of why some elongations of Mercury (and Venus) are more favourable than others.

The Sun—During November, the sun's R.A. increases from 14 h 24 m to 16 h 28 m and its Decl. changes from −14° 20′ to −21° 45′. The equation of time changes from +16 m 23 s to +11 m 14 s.

The Moon—On Nov. 1.0 E.S.T., the age of the moon is 4.0 d. The sun's selenographic colongitude is 320.5° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Nov. 18 (8°) and minimum (east limb exposed) on Nov. 6 (8°). The libration in latitude is maximum (north limb exposed) on Nov. 10 (7°) and minimum (south limb exposed) on Nov. 23 (7°).

Mercury on the 1st is in R.A. 13 h 17 m, Decl. −5° 58′, and on the 15th is in R.A. 14 h 25 m, Decl. −12° 40′. Greatest elongation west (19°) occurs on Nov. 2, and this is a favourable elongation for northern observers: the planet stands about 17° above the south-eastern horizon at sunrise. Jupiter, Saturn and Spica figure prominently in this picture. Mercury is 5° north of Spica on Nov. 2, and 1.2° north of Jupiter on Nov. 5.

Venus on the 1st is in R.A. 17 h 39 m, Decl. −26° 40′, and on the 15th it is in R.A. 18 h 43 m, Decl. −26° 34′, mag. −4.1, and transits at 15 h 07 m. It can be seen low in the south-west, just after sunset. Greatest elongation east (47°) occurs on Nov. 10, but this is an unfavourable elongation for northern observers, in part because of the shallow angle between the ecliptic and the horizon, and in part because Venus is south of the ecliptic.

Mars on the 15th is in R.A. 11 h 04 m, Decl. +7° 51′, mag. +1.5, and transits at 7 h 27 m. It rises after midnight, and is nearly at the meridian by sunrise. Throughout the month, it moves eastward under the lion towards Virgo.

Jupiter on the 15th is in R.A. 13 h 44 m, Decl. −9° 35′, mag. −1.2, and transits at 10 h 06 m. In Virgo, it rises about 4 hours after midnight, and is well up in the south-east at sunrise. As the end of the year approaches, Spica, Jupiter, Saturn, Mars and Regulus form a conspicuous parade across the morning sky.

Saturn on the 15th is in R.A. 13 h 08 m, Decl. −4° 47′, mag. +1.0, and transits at 9 h 30 m. In Virgo, it rises about 3 hours after midnight, and is well up in the south-east at sunrise. See also "Jupiter" above. On Nov. 16–17, it passes near θ Vir.

Uranus on the 15th is in R.A. 15 h 51 m, Decl. −19° 58′, mag. +6.0, and transits at 12 h 13 m. It is in conjunction on Nov. 22, 14 h.

Neptune on the 15th is in R.A. 17 h 32 m, Dec. −22° 01′, mag. +7.8, and transits at 13 h 53 m.

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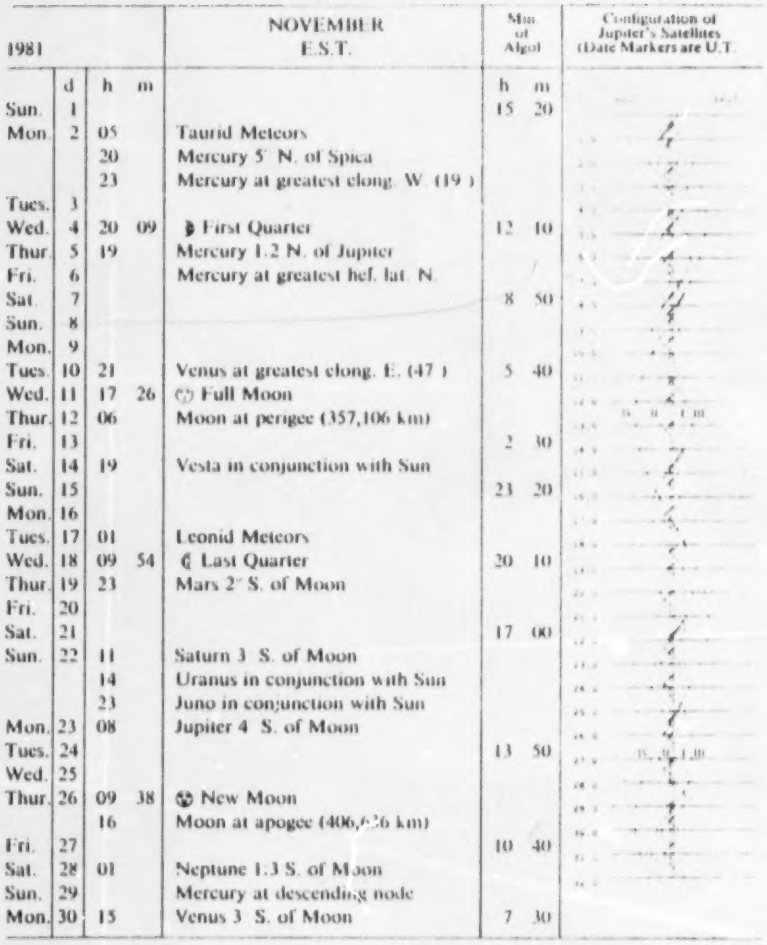
1981	d	h	m	NOVEMBER E.S.T.	Min of Algol h	m
Sun.	1				15	20
Mon.	2	05		Taurid Meteors		
		20		Mercury 5° N. of Spica		
		23		Mercury at greatest elong. W. (19°)		
Tues.	3					
Wed.	4	20	09	☽ First Quarter	12	10
Thur.	5	19		Mercury 1.2 N. of Jupiter		
Fri.	6			Mercury at greatest hel. lat. N.		
Sat.	7				8	50
Sun.	8					
Mon.	9					
Tues.	10	21		Venus at greatest elong. E. (47°)	5	40
Wed.	11	17	26	☽ Full Moon		
Thur.	12	06		Moon at perigee (357,106 km)		
Fri.	13				2	30
Sat.	14	19		Vesta in conjunction with Sun		
Sun.	15				23	20
Mon.	16					
Tues.	17	01		Leonid Meteors		
Wed.	18	09	54	☾ Last Quarter	20	10
Thur.	19	23		Mars 2° S. of Moon		
Fri.	20					
Sat.	21				17	00
Sun.	22	11		Saturn 3° S. of Moon		
		14		Uranus in conjunction with Sun		
		23		Juno in conjunction with Sun		
Mon.	23	08		Jupiter 4° S. of Moon		
Tues.	24				13	50
Wed.	25					
Thur.	26	09	38	● New Moon		
		16		Moon at apogee (406,626 km)		
Fri.	27				10	40
Sat.	28	01		Neptune 1.3 S. of Moon		
Sun.	29			Mercury at descending node		
Mon.	30	15		Venus 3° S. of Moon	7	30

Configuration of Jupiter's Satellites (Date Markers are U.T.)



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Looking Ahead to 1982. Observers who want to know about astronomical phenomena well in advance should obtain the booklet *Astronomical Phenomena for the Year 1982* (or whatever). It is prepared by the Nautical Almanac Office at the U.S. Naval Observatory, and by Her Majesty's Nautical Almanac Office at the Royal Greenwich Observatory in England. It can be obtained from the U.S. Government Printing Office, Washington, or from Her Majesty's Stationery Office, London.

According to this booklet, there will be seven eclipses in 1982, three of the moon (all total) and four of the sun (all partial). Two of the former are visible from North America, but none of the latter. This is the maximum number of eclipses in a year, and it occurs when the "eclipse seasons" are in January and December.

There will be a series of 12 occultations of Neptune by the moon. None of these is visible from North America.

Late in the year, the sun and major planets will gather together in Virgo to produce the notorious "alignment" which you may have read about. The alignment, however, is far from exact, and the combined gravitational and other effects of the assembled planets will be minuscule compared with the normal gravitational and other effects of the sun. Unfortunately, with the major planets so near the sun in the sky, it will be a rather unrewarding time for planet-watchers.

The Sun—During December, the sun's R.A. increases from 16 h 28 m to 18 h 45 m and its Decl. changes from −21° 45′ to −23° 03′. The equation of time changes from +10 m 51 s to −3 m 09 s. The sun reaches the winter solstice on Dec. 21, 17 h 51 m, E.S.T., and winter begins in the northern hemisphere.

The Moon—On Dec. 1.0 E.S.T., the age of the moon is 4.2 d. The sun's selenographic colongitude is 325.5° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Dec. 16 (8°) and minimum (east limb exposed) on Dec. 4 (8°). The libration in latitude is maximum (north limb exposed) on Dec. 7 (7°) and minimum (south limb exposed) on Dec. 20 (7°).

Mercury on the 1st is in R.A. 16 h 05 m, Decl. −20° 58′, and on the 15th is in R.A. 17 h 40 m, Decl. −24° 53′. Throughout the month it is too close to the sun to be easily seen, being in superior conjunction on Dec. 10.

Venus on the 1st is in R.A. 19 h 46 m, Decl. −24° 12′, and on the 15th it is in R.A. 20 h 26 m, Decl. −20° 52′, mag. −4.4, and transits at 14 h 50 m. Throughout the month it can be seen low in the south-west, just after sunset. Greatest brilliancy (−4.4) is on Dec. 16.

Mars on the 15th is in R.A. 12 h 02 m, Decl. +2° 07′, mag. +1.2, and transits at 6 h 26 m. In Virgo, it rises about midnight and is west of the meridian at sunrise.

Jupiter on the 15th is in R.A. 14 h 06 m, Decl. −11° 33′, mag. −1.3, and transits at 8 h 30 m. In Virgo, it rises about 3 hours after midnight and is near the meridian by sunrise.

Saturn on the 15th is in R.A. 13 h 19 m, Decl. −5° 46′, mag. +1.0, and transits at 7 h 43 m. In Virgo, it rises about 2 hours after midnight, and is on the meridian by sunrise.

Uranus on the 15th is in R.A. 15 h 59 m, Decl. −20° 21′, mag. +6.0, and transits at 10 h 22 m.

Neptune on the 15th is in R.A. 17 h 36 m, Decl. −22° 04′, mag. +7.8, and transits at 11 h 59 m. On Dec. 1, it passes very close to 52 Oph, but it is also very close to the sun at this time, being in conjunction on Dec. 16, at 10 h.

1981				DECEMBER E.S.T.	Min of Algol	Configuration of Jupiter's Satellites (Date Markers are U.T.)
	d	h	m		h m	
Tues.	1					
Wed.	2					
Thur.	3				4 20	
Fri.	4	11	22	☽ First Quarter		
Sat.	5			Mars at greatest hel. lat. N.		
Sun.	6				1 00	
Mon.	7					
Tues.	8				21 50	
Wed.	9					
Thur.	10			Mercury at aphelion		
		10		Mercury in superior conjunction		
		19		Moon at perigee (356,809 km)		
Fri.	11	03	41	☉ Full Moon	18 40	
Sat.	12					
Sun.	13	23		Geminid Meteors		
Mon.	14				15 30	
Tues.	15					
Wed.	16	10		Neptune in conjunction with Sun		
		14		Venus greatest brilliancy (−4.4)		
Thur.	17				12 20	
Fri.	18	00	47	☾ Last Quarter		
		08		Mars 3° S. of Moon		
Sat.	19	22		Saturn 3° S. of Moon		
Sun.	20				9 10	
Mon.	21	01		Jupiter 4° S. of Moon		
		17	51	Winter Solstice. Winter begins		
Tues.	22	08		Ursid Meteors		
Wed.	23	10		Uranus 4° S. of Moon	6 00	
		18		Moon at apogee (406,376 km)		
Thur.	24			Venus at ascending node		
		11		Vesta 0.1 S. of Moon. Occ'n		
Fri.	25					
Sat.	26	05	10	● New Moon	2 50	
Sun.	27					
Mon.	28				23 40	
Tues.	29	00		Venus 2° N. of Moon		
Wed.	30			Mercury at greatest hel. lat. S.		
		03		Venus stationary		
Thur.	31					

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THE PLANETS FOR 1981

By Terence Dickinson

MERCURY

At just over one-third Earth's distance from the sun, Mercury is the solar system's innermost planet and the only one known to be almost entirely without an atmosphere. Mercury is a small world only 6% as large as the Earth by volume—barely larger than our moon.

Until the advent of interplanetary probes, virtually nothing was known about the surface of Mercury. Only the vaguest smudges have been seen through Earth-based telescopes. In 1974 the U.S. spacecraft Mariner 10 photographed one hemisphere of Mercury revealing it to be extremely heavily cratered, in many respects identical in appearance to the far side of Earth's moon. There is no interplanetary mission planned to photograph the other hemisphere.

Mercury's orbit is the most elliptical of any planet except Pluto's. Once each orbit Mercury approaches to within 0.31 A.U. of the sun and then half an orbit (44 days) later it is out to 0.47 A.U. This amounts to a 24 million km range in distance from the sun, making the sun in Mercury's sky vary from about four times the area we see it to more than ten times its apparent area from Earth. Mercury's sidereal rotation period of 59 days combines with the 88 day orbital period of the planet to produce a solar day (one sunrise to the next) of 176 days—the longest of any planet.

Of the five planets visible to the unaided eye Mercury is by far the most difficult to observe and is seldom conveniently located for either unaided eye or telescopic observation. The problem for observers is Mercury's tight orbit which constrains the planet to a small zone on either side of the sun as viewed from Earth. When Mercury is east of the sun we may see it as an evening star low in the west just after sunset. When it is west of the sun we might view Mercury as a morning star in the east before sunrise. But due to celestial geometry involving the tilt of the Earth's axis and Mercury's orbit we get much better views of Mercury at certain times of the year.

The best time to see the planet in the evening is in the spring and in the morning in the fall (from the northern hemisphere). Binoculars are of great assistance in searching for the planet about 40 minutes to an hour after sunset or before sunrise during the periods when it is visible. Mercury generally appears about the same colour and brightness as the planet Saturn.

Telescopic observers will find the rapidly changing phases of Mercury of interest. The planet appears to zip from gibbous to crescent phase in about three weeks during each of its elongations. In the table below the visual magnitude, phase and apparent diameter of Mercury as seen through a telescope are tabulated for two of the most favourable elongations.

GREATEST ELONGATIONS OF MERCURY IN 1981

Date E.S.T.	Elong.	Mag.	App. Diam.
	°		"
Feb. 1	18E	−0.3	6.8
Mar. 15	28W	+0.4	7.2
*May 26	23E	+0.6	8.0
July 14	21W	+0.5	7.7
Sept. 23	26E	+0.3	6.8
*Nov. 2	19W	−0.3	6.7

*favourable elongations

MERCURY: TELESCOPIC OBSERVING DATA FOR FAVOURABLE EASTERN ELONGATIONS 1981

Date 19h EST	Magnitude	Apparent Diameter	Phase % illuminated	R.A.	Dec.
		"		h m	° '
Jan. 21	−0.9	5.5	88	21 15	−17 40
25	−0.8	5.6	79	21 39	−15 10
29	−0.6	6.4	66	20 01	−12 32
Feb. 2	−0.2	7.2	49	22 16	−10 05
6	+0.4	8.1	30	22 24	−8 12
May 13	−0.5	6.1	71	4 34	+24 08
17	−0.1	6.6	60	5 03	+25 08
21	+0.2	7.2	49	5 28	+25 33
25	+0.6	7.9	40	4 49	+25 29
29	+0.9	8.6	31	6 01	+25 10

Mercury's phases have been glimpsed with telescopes of 3-inch aperture or less, but generally a 4-inch or larger telescope is required to distinguish them. In larger instruments under conditions of excellent seeing (usually when Mercury is viewed in the daytime) dusky features have been glimpsed by experienced observers. Recent analysis has shown only a fair correlation between these visually observed features and the surface of the planet as photographed by Mariner 10.

VENUS

Venus is the only planet in the solar system that closely resembles Earth in size and mass. It also comes nearer to the Earth than any other planet, at times approaching as close as 41 million km. Despite the fundamental similarity, Earth and Venus differ greatly according to findings of recent spacecraft missions to the planet.

We now know that Venus is infernally hot over its entire surface, ranging little from a mean of +480° C. The high temperature is due to the dense carbon dioxide atmosphere of Venus which, when combined with small quantities of water vapour and other gases known to be present, has the special property of allowing sunlight to penetrate to the planet's surface but not permitting the resulting heat to escape. In much the same way as the glass cover of a greenhouse keeps plants warm, an atmosphere of carbon dioxide can heat up a planetary surface to a higher temperature than would be achieved by normal sunlight.

Venus' atmosphere has a surface pressure in excess of 90 times Earth's sea-level atmospheric pressure. A thick haze layer extends down from a level about 65 kilometers above the surface. However, the Soviet Venera 9 and 10 spacecraft that landed on Venus in 1975 and photographed the planet's surface showed that sunlight similar to that received on Earth on a heavily overcast day does penetrate down to the surface, proving that previously predicted layers of opaque clouds do not exist. The cloud-like haze that cloaks the planet, believed to consist chiefly of droplets of sulphuric acid, is highly reflective making Venus brilliant in the nighttime sky. However, telescopically the planet is virtually a featureless orb.

Results from the U.S. Pioneer and Soviet Venera robot explorations of Venus in 1978 added substantially to our knowledge of the veiled planet. The Soviet and

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VENUS: TELESCOPIC OBSERVING DATA 1981

Date	Magnitude	Apparent Diameter	Phase (% illuminated)
Jan. 1	−3.4	11.1	92
Feb. 1	−3.3	10.4	96
June 1	−3.3	10.2	97
July 1	−3.3	10.9	92
Aug. 1	−3.4	12.2	85
Sept. 1	−3.5	14.2	77
Oct. 1	−3.7	17.2	67
Nov. 1	−3.9	22.5	54
Dec. 1	−4.3	32.2	38
Dec. 10	−4.4	37.1	32
Dec. 20	−4.4	43.1	23
Dec. 30	−4.3	51.1	14

American landing devices detected what appears to be evidence of periods of virtually continuous lightning in the atmosphere and of a continuous glow at night near Venus' surface. "Chemical fires" due to reactions of various compounds in the super-heated atmosphere close to, or on, Venus' surface have been cited as a possible source for the glow. The Pioneer Orbiter's infrared radiometer found both a depression in the clouds at the north pole, and an actual 1100 km hole where there were few or no clouds. This finding strongly suggests a downflow of atmosphere at the pole. New probe findings also show that below the clouds Venus' atmosphere is remarkably uniform in temperature and pressure at all latitudes and in both day and night hemispheres.

Based on extensive radar data returned from the Pioneer Orbiter, nearly the entire planet has been mapped. Sixty percent of Venus' surface is relatively flat; rolling plains varying in height by only about one km between high and low points. Only 16 percent of the surface could be described as lowlands (perhaps comparable to ocean basins on Earth). Only eight percent is true highland, ranging to a maximum altitude of 10.6 km above the rolling plains. Venus' crust appears to be thicker than Earth's—thick enough to choke off plate tectonics. Apparently, Venus' crust is one huge tectonic plate. There is no evidence of features like Earth's midocean ridges.

Venus is the brightest natural celestial object in the nighttime sky apart from the moon and whenever it is visible is readily recognized. Because its orbit is within that of the Earth, Venus is never separated from the sun by an angle greater than 47 degrees. However, this is sufficient for it to be seen in black skies under certain conditions and at these times it is a truly dazzling object. Such circumstances occur during January in the eastern morning sky and, for the last half of the year, in the west during the early evening.

Like Mercury, Venus exhibits phases although they are much easier to distinguish because of Venus' greater size. When it is far from us (near the other side of its orbit) we see the planet nearly fully illuminated, but because of its distance it appears small —about 10 seconds of arc in diameter. As Venus moves closer to Earth the phase decreases (we see less of the illuminated portion of the planet) but the diameter increases until it is a thin slice nearly a minute of arc in diameter. It takes Venus several months to run through from one of these extremes to the other compared to just a few weeks for Mercury.

When Venus is about a 20% crescent even rigidly held good quality binoculars can be used to distinguish that the planet is not spherical or a point source. A 60 mm refractor should be capable of revealing all but the gibbous and full phases of Venus.

Experienced observers prefer to observe Venus during the daytime and indeed the planet is bright enough to be seen with the unaided eye if one knows where to look.

Venus appears to most observers to be featureless no matter what type of telescope was used or what the planet's phase. However, over the past century some observers using medium or large size telescopes have reported dusky, patchy marking usually described as slightly less brilliant than the dazzling white of the rest of the planet. We now know that there are many subtle variations in the intensity of the clouds of Venus as photographed in ultraviolet by Earth-based telescopes and by the cameras of Mariner 10 as it swung by the planet in February 1974. But when the ultraviolet photos are compared to drawings of the patchy markings seen by visual observers the correlation is fair at best.

When Venus is less than 10% illuminated the cusps (the points at the ends of the crescent) can sometimes be seen to extend into the night side of the planet. This is an actual observation of solar illumination being scattered by the atmosphere of Venus. When Venus is a thin sliver of a crescent the extended cusps may be seen to ring the entire planet.

MARS

Mars is the planet that has long captivated the imagination of mankind as a possible abode of life. One of the major objectives of the Viking spacecraft which landed on Mars in 1976 was the quest for Martian microorganisms. The Viking biology experiments completed the search in 1977 and, although the results are somewhat ambiguous, there is no convincing evidence of life we are familiar with.

The landscapes photographed by the Viking landers were basically desert vistas strewn with rocks ranging up to several meters wide. Judging by their texture and colour, and chemistry analysis by Viking, the rocks are fragments of lava flows. The soil composition resembles that of basaltic lavas on the Earth and moon. About 1% of the soil is water, chemically bound in the crystal structure of the rock and soil particles. Some planetary scientists speculate that water in the form of permafrost exists a few meters below the surface. However, Viking and its predecessors have shown that water was once abundant enough on Mars to leave major structures on the planet resembling riverbeds. Analysis of high resolution Viking Orbiter photographs of these structures has led most investigators to conclude that they were likely carved during the planet's early history.

The red planet's thin atmosphere has an average surface pressure only 0.7% of Earth's and consists of 95% carbon dioxide, 2.7% nitrogen, 1.6% argon, 0.6% carbon monoxide, 0.15% oxygen and 0.03% water vapour. Winds in the Martian atmosphere reach velocities exceeding 300 km per hour and in so doing raise vast amounts of dust that can envelop the planet for weeks at a time. The dust storms were thought to occur with seasonal regularity shortly after Mars passed the perihelion point of its elliptical orbit, but the Viking observations revealed more complex weather patterns.

In January Mars is low in the west after sunset and poorly placed for telescopic observation. From February to June it is too close to the sun for convenient viewing, and although it climbs higher in the morning sky as the last half of the year progresses, the planet is not well placed for telescopic scrutiny.

In many ways Mars is the most interesting planet to observe with the unaided eye. It moves rapidly among the stars—its motion can usually be detected after an interval of less than a week—and it varies in brightness over a far greater range than any other planet. Mars may be distinguished by its orange-red colour, a hue that originates with rust-coloured dust that covers much of the planet.

Telescopically Mars is usually a disappointingly small featureless ochre disk except within a few months of opposition when its distance from the Earth is then near minimum. If Mars is at perihelion at these times the separation can be as little as 56 million km. Such close approaches occur at intervals of 15 to 17 years; the most

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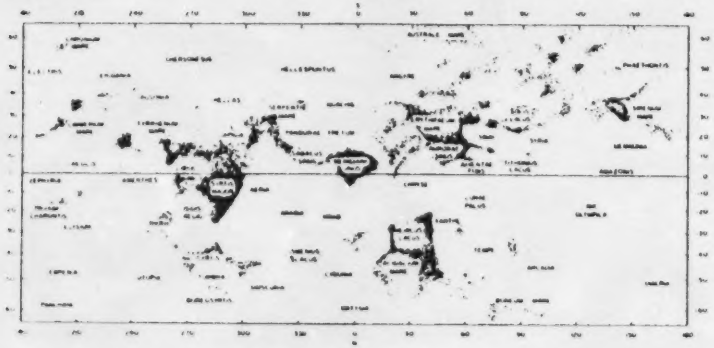
MARS: EPHEMERIS FOR PHYSICAL OBSERVATIONS 1981

Date U.T.	Dist. A.U.	Vis. Mag.	App. Diam.	% Ill.	Pos. Ang.	Incl.	L(1)	Δ
July 1.0	2.411	+1.7	3.88	99	329	−2	131.45	9.72
Aug. 1.0	2.347	+1.8	3.99	97	339	+7	190.17	9.71
Sept. 1.0	2.233	+1.8	4.19	96	351	+14	249.10	9.72
Oct. 1.0	2.071	+1.7	4.52	94	2	+20	317.52	9.72
Oct. 15.0	1.977	+1.7	4.73	93	8	+22	181.41	9.72
Nov. 1.0	1.849	+1.6	5.06	92	14	+24	16.24	9.70
Nov. 15.0	1.733	+1.5	5.40	92	19	+24	240.44	9.67
Dec. 1.0	1.590	+1.3	5.88	91	23	+24	85.69	9.63
Dec. 15.0	1.457	+1.1	6.43	90	27	+24	310.88	9.57
Jan. 1.0	1.291	+0.9	7.25	90	30	+23	148.23	—

recent was in 1971. At a perihelion opposition the telescopic disk of Mars is 25 seconds of arc in diameter and much detail on the planet can be distinguished with telescopes of 4-inch aperture or greater. At oppositions other than when Mars is at perihelion the disk is correspondingly smaller. There is no opposition of Mars in 1981.

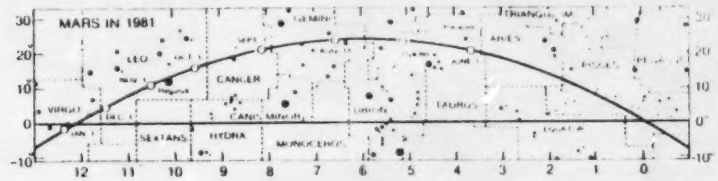
For selected dates when Mars is favourably placed, the table above gives the distance from the earth, the magnitude, apparent diameter, fraction of the disk illuminated, position angle of the rotation axis (measured from the north through the east), inclination of the rotation axis to the plane of the sky (positive if the north pole is tipped toward the earth) and two quantities *L(1)* and Δ which can be used to calculate the longitude *L* of the central meridian of the geometric disc. To calculate *L*, note the date and time of the observation, and then convert them to U.T. (see section on *Time*). Take *L(1)* for the first date in the table preceding the date of observation, and from it *subtract* Δ times the number of full days elapsed since the first date in the table preceding the date of observation. To the result, *add* 14.6° for each hour elapsed since 0 h U.T. If the result is less than 0°, *add* 360°; if the result is greater than

MAP OF MARS



Latitude is plotted on the vertical axis (south at the top); longitude is plotted on the horizontal axis

360°, *subtract* 360°. This formula replaces the tables given in past years; it is accurate to better than 1°. The value of *L* can then be compared with the map on pg. 82.



During opposition period the north pole of Mars is tipped strongly toward the Earth and the north polar cap should be the most prominent feature visible in small telescopes. The main features on the map of Mars can be seen with a good 4-inch telescope when the planet is within 1 A.U. of the Earth. The features of the map can be correlated to the planet's rotation by use of the table.

JUPITER

Jupiter, the solar system's largest planet, is a colossal ball of hydrogen and helium without any solid surface comparable to land masses on Earth. In many respects Jupiter is more like a star than a planet. Jupiter likely has a small rocky core encased in a thick mantle of metallic hydrogen which is enveloped by a massive atmospheric cloak topped by a quilt of multi-coloured clouds.

The windswept visible surface of Jupiter is constantly changing. Vast dark belts merge with one another or sometimes fade to insignificance. Brighter zones—actually smeared bands of ammonia clouds—vary in intensity and frequently are carved up with dark rifts or loops called festoons. The equatorial region of Jupiter's clouds rotates five minutes faster than the rest of the planet: 9 hours 50 minutes compared to 9 hours 55 minutes. This means constant interaction as one region slips by the other at about 400 km/hr. It also means that there are basically two rotational systems from the viewpoint of week-to-week telescopic observation.

In the table below the two quantities L(1) and Δ can be used to calculate the longitude of the central meridian of the illuminated disk of Jupiter. System I is the most

JUPITER: EPHEMERIS FOR PHYSICAL OBSERVATIONS 1981

Date U.T.	Vis. Mag.	App. Equat. Diam.	System I		System II	
			L(1)	Δ	L(1)	Δ
Jan. 1.0	−1.6	36.9	122.5	157.95	127.4	150.30
Feb. 1.0	−1.8	40.5	338.9	158.00	107.2	150.40
Mar. 1.0	−2.0	43.2	83.2	158.05	357.9	150.40
Apr. 1.0	−2.0	44.2	302.3	157.95	340.4	150.35
May 1.0	−1.9	42.5	1.4	157.85	170.7	150.25
June 1.0	−1.7	39.2	215.2	157.75	147.9	150.15
July 1.0	−1.6	35.9	268.1	157.70	332.0	150.10
Aug. 1.0	−1.4	33.2	116.9	157.65	304.2	150.05
Sept. 1.0	−1.3	31.4	324.7	157.65	275.5	150.05
Oct. 1.0	−1.2	30.6	14.8	157.70	96.7	150.05
Nov. 1.0	−1.2	30.7	223.1	157.75	68.5	150.10
Dec. 1.0	−1.3	31.8	275.2	157.80	251.7	150.15
Jan. 1.0	−1.4	33.9	127.1	157.85	226.9	150.25

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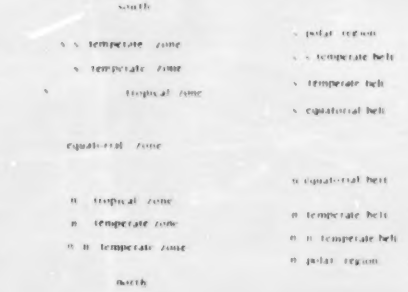
rapidly rotating region between the middle of the North Equatorial Belt and the middle of the South Equatorial Belt. System II applies to the rest of the planet. For a given date and time (U.T.) of observation, the central meridian longitude is equal to I (I) for the month in question plus A times the number of complete days elapsed since 0 h U.T. on the first of the month plus either 36.58 (for system I) or 36.26 (for system II) times the number of hours elapsed since 0 h U.T. The result will usually exceed 360 ; if so, divide the result by 360 and then multiply the decimal portion of the quotient by 360 . This procedure, which is accurate to 1 and is readily computed using a modest calculator, replaces the tables given in previous editions of the HANDBOOK.

Jupiter's rapid rotation also makes the great globe markedly oval so that it appears about 7"„ "squashed" at the poles. Jupiter's apparent equatorial diameter ranges from 44" at opposition on March 27 to a minimum of 31" at conjunction on October 14.

JUPITER'S BELTS AND ZONES

Viewed through a telescope of 6-inch aperture or greater, Jupiter exhibits a variety of changing detail and colour in its cloudy atmosphere. Some features are of long duration, others are short-lived. The standard nomenclature of the belts and zones is given in the figure.



The Great Red Spot, a towering vortex whose colour may possibly be due to organic-like compounds that are constantly spewed from some heated atmospheric source below, is the most conspicuous and longest-lived structure on the visible surface of Jupiter. The spot and the changing cloud structures can be easily observed in small telescopes because the apparent size of the visible surface of Jupiter is far greater than that of any other planet.

Two Voyager spacecraft swung through the Jovian system in 1979 and transmitted to Earth superbly detailed photographs of the planet and its five inner moons. Among the most surprising finds was a ring of dust-size particles around the giant planet's equator. The ring apparently extends from the Jovian clouds out to 59,000 km. The outer 1000 km of the ring is its brightest zone but its proximity to the planet makes recent claims of its detection from Earth some years ago controversial.

The smallest of telescopes will reveal Jupiter's four large moons, each of which is equal to or larger than Earth's satellite. The moons provide a never-ending fascination for amateur astronomers. Sometimes the satellites are paired on either side of the belted planet; frequently one is missing—either behind Jupiter or in the planet's shadow. Even more interesting are the occasions when one of the moons casts its shadow on the disk of the planet. The tiny black shadow of one of the moons can be particularly evident if it is cast on one of the bright zones of Jupiter. According to some observers this phenomenon is evident in a good 60 mm refractor. Both the

satellite positions and the times of their interaction with the Jovian disk are given elsewhere in the HANDBOOK. Jupiter's other satellites are photographic objects for large instruments.

As 1981 opens Jupiter is in Virgo, flanked by Saturn, which has conjunctions with Jupiter on January 14, February 19, and July 30. Jupiter is by far the brighter of the two planets and is ideally placed for telescopic study for the first half of the year. Despite the fact that it is five times Earth's distance from the sun Jupiter's giant size and effective clouds make it a celestial beacon that is unmistakable, particularly around opposition.

Opposition this year occurs on March 27 when the giant planet is 666 million km (4.44 A.U.) from Earth. Minimum possible distance between the two planets is 590 million km.

SATURN

Saturn is the telescopic showpiece of the night sky. The chilling beauty of the small pale orb floating in a field of velvet is something no photographs or description can adequately duplicate. The rings consist of billions of particles which, according to recent photometric, radar and other data, are believed to be approximately fist-sized and made of—or covered by—water ice. This would account for their exceedingly high reflectivity. The reason that "rings" is plural and not singular is that gaps and brightness differences define distinct rings.

The outer ring A has an external diameter of 274,000 km and is 16,000 km wide. Separating ring A from the 26,000 km-wide ring B is a 3,000 km gap known as Cassini's Division which appears to be virtually free of ring particles. The gap was discovered in 1675 and is visible in good quality telescopes of 60 mm aperture when the ring system is well inclined to our view from Earth. Ring B, the brightest, overpowers ring C to such an extent that it is seen only with difficulty in small telescopes. Ring C, also known as the crepe ring, extends 16,000 km toward Saturn from the inner edge of ring B.

Pioneer 11, which hurtled by Saturn in 1979, detected particles both inside and outside the three rings visible from Earth as well as in the gaps between them. The content, extent, and structure of the rings are being dramatically refined by examination of data returned from the Voyager 1 spacecraft, which is nearing Saturn as the HANDBOOK goes to press.

In addition to the rings Saturn has a family of at least 10 satellites. Titan, the largest, is easily seen in any telescope as an eighth magnitude object orbiting Saturn in about 16 days. At east and west elongation Titan appears about five ring diameters from the planet. Titan is believed to be unique as the only satellite in the solar system with a substantial atmosphere. Estimates of its density range from 0.1 to equal Earth's although its primary known constituent is methane.

Telescopes over 60 mm aperture should reveal Rhea at 10th magnitude less than two ring-diameters from Saturn. The satellite Iapetus has the peculiar property of being five times brighter at western elongation (10.1) than at eastern elongation (11.9). One side of the moon has the reflectivity of snow while the other resembles dark rock. The reason for this is unknown. When brightest, Iapetus is located about 12 ring-diameters west of its parent planet. Of the remaining moons Tethys and Dione may be glimpsed in a 15 cm telescope but the others require larger apertures or photographic techniques.

The disk of Saturn appears about 1/6 the size Jupiter appears through the same telescope with the same magnification. In telescopes less than 4 inches aperture

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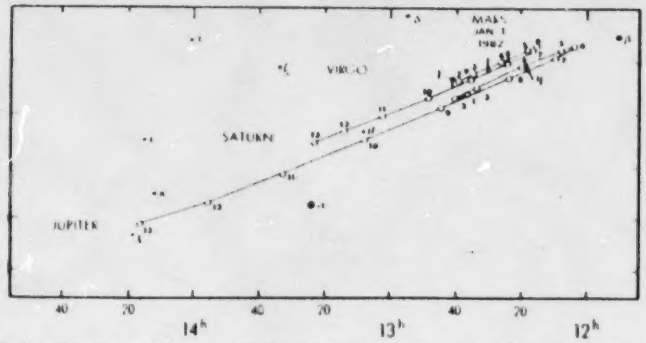

The Paths of Jupiter and Saturn in 1981. The positions are marked for the first day of each month: (1) January, (2) February, etc.

probably no features will ever be seen on the surface of the planet other than the shadow cast by the rings. As the size of the telescope is increased the whitish equatorial region and the darker polar regions become evident. Basically, Saturn has a belt system like Jupiter's but it is much less active and the contrast is reduced. Seldom in telescopes less than 8-inch aperture do more than one or two belts come into view. In 1980, the planet's rotation period was established at 10 hours, 40 minutes, four per cent longer than previous estimates. Very rarely a spot among the Saturnian clouds will appear unexpectedly, but less than a dozen notable spots have been recorded since telescopic observation of Saturn commenced in the 17th century.

From year to year the rings of Saturn take on different appearances. The planet's orbit is an immense 29.5 year circuit about the sun, so in the course of an observing season the planet moves relatively little in its orbit (and thus appears to remain in about the same general area of the sky) and maintains an essentially static orientation toward the Earth. In 1973 the rings were presented to their fullest extent (27°) as viewed from the Earth. In apparent width the rings are equal to the equatorial diameter of Jupiter.

As 1981 opens, the rings are tilted 7.3° with respect to Earth with the northern face being visible. This value remains essentially constant through January, then decreases to 6.5° by March 1, 5.4° by April 1, and 4.4° by May 1. From then until September, when Saturn is too close for observation, the ring inclination slowly increases back to about 7°. By December 31, when Saturn is well up in the morning sky, the rings have opened to 12.2°.

Both Saturn and Jupiter are in Virgo and rise at about midnight as 1981 begins. Both planets remain in Virgo all year and are in conjunction on January 14, February 19, and July 30. Saturn opposition is March 27, when the planet is 1.28 billion km (8.53 AU) from Earth. At that time the planet is 19.5″ in equatorial diameter and the rings are 43.8″ in width.

URANUS

Although Uranus can be seen with the unaided eye under a clear, dark sky it was apparently unknown until 1781 when it was accidentally discovered by William Herschel with a 6-inch reflecting telescope. It can be easily seen with binoculars and a telescope will reveal its small greenish featureless disk.

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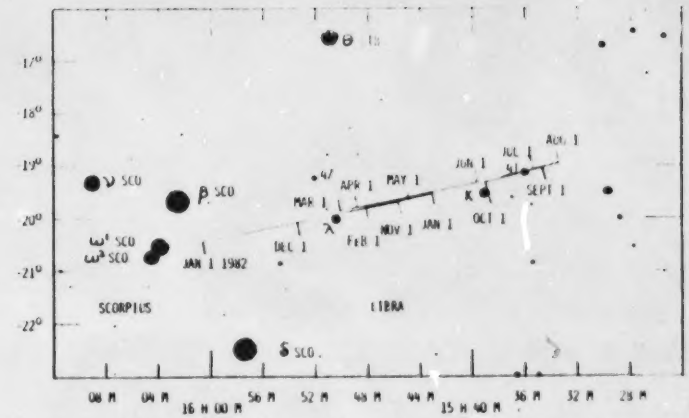

The Path of Uranus in 1981. Positions for first day of each month. The faintest stars are about magnitude 8.

Jupiter, Saturn, Uranus and Neptune are rather similar in the sense that their interiors consist mainly of hydrogen and helium and their atmospheres consist of these same elements and simple compounds of hydrogen. Unlike the three other giant planets, the axis of Uranus is tipped almost parallel to the plane of the solar system. This means that we can view Uranus nearly pole-on at certain points in its 84 year orbit of the sun. The northern hemisphere of Uranus is now directed toward the Earth and we will be viewing the planet almost exactly toward its north pole in 1985. Uranus has five satellites, all smaller than Earth's moon, none of which can be detected in small or moderate sized telescopes.

The 1977 discovery of at least five rings encircling Uranus is regarded as one of the major planetary finds in recent years. Their detection emerged during a relatively routine occultation observation from an airborne observatory—an experiment initially intended to provide a more accurate measure of the diameter of Uranus. Refinement of the observations and results from another occultation in 1978 indicates there is evidence for eight (possibly nine) rings relatively evenly spaced from 16,000 to 24,000 km above the cloudy surface of Uranus. The outer ring is about 100 km wide but curiously eccentric. The others are estimated to be between 5 and 10 km across.

These dimensions are markedly different from Saturn's three major rings, each of which is thousands of kilometers wide. Although different in scale, the composition of the Uranian rings should be fundamentally the same as Saturn's—swarms of particles varying from dust-size up to small flying mountains each in its own orbit. The rings are not as dense as Saturn's major ring since the occulted star did not completely disappear during passage behind them. Also, the albedo of the individual particles is believed to be low suggesting a dark substance compared to Saturn's brilliantly reflective ring material. The Uranian rings are invisible by direct visual observation because of their small dimensions and the enormous distance that separates us from Uranus.

Estimates of Uranus' diameter made over the last half century range from 46,000 to 56,000 km depending on the technique employed. Some recent work supports the high end of this range. If this proves to be correct then Uranus, like Saturn, has an average density less than that of water. The long quoted rotation period of Uranus (about 11 hours) has come into question recently and may be in error by a factor of

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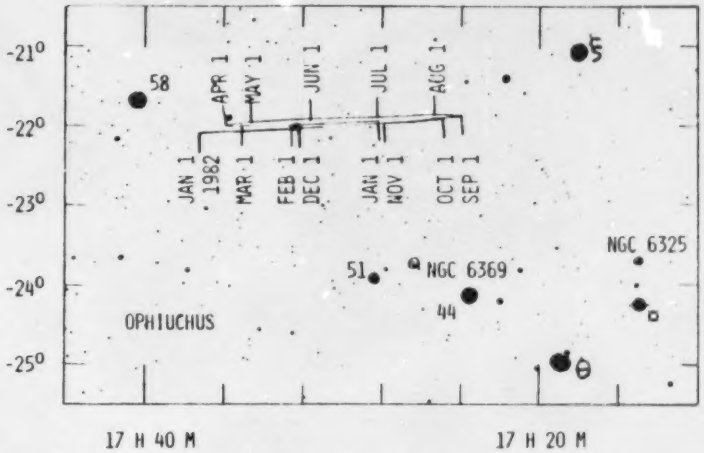
at least 2. A Kitt Peak National Observatory study in 1977 yielded a 23-hour period while researchers elsewhere have obtained other figures in the 12 to 24 hours range.

Uranus is in Libra for most of 1981, opposition being on May 19 when the planet is 2.66 billion km (17.80 AU) from Earth. At this time its magnitude is +5.8 and its apparent diameter is 3.9 seconds of arc.

NEPTUNE

The discovery of Neptune in 1846, after its existence in the sky had been predicted from independent calculations by Leverrier in France and Adams in England, was regarded as the crowning achievement of Newton's theory of universal gravitation. Actually Neptune had been seen—but mistaken for a star—several times before its "discovery".



The Path of Neptune in 1981. Positions for first day of each month. The faintest stars are about magnitude 10.

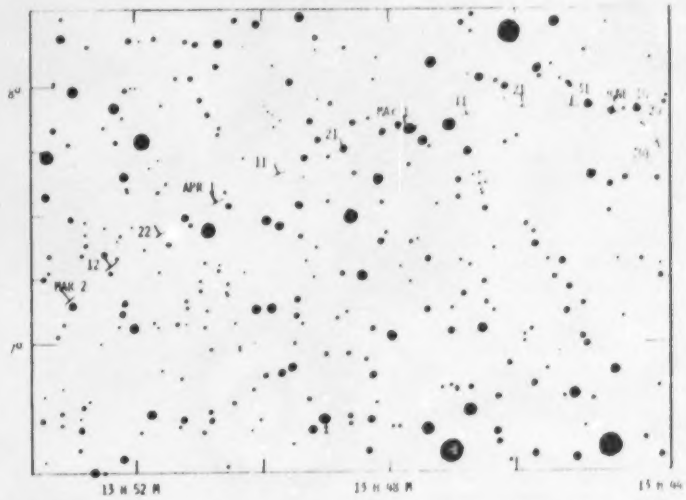
Telescopically the planet appears as a 2.5 second of arc featureless bluish-green disk. Neptune's large moon Triton can be seen by an experienced observer using a 12-inch telescope. Triton is an exceptionally large satellite and may prove to be the solar system's biggest moon. The moon varies from 8 to 17 seconds of arc from Neptune during its 5.9 day orbit.

No surface features have ever been distinctly seen on Neptune's visible surface. The planet's rotation period, determined spectroscopically, was tentatively revised upward to 22 hours in 1977. Neptune's diameter is known with high precision due to analysis of a series of observations of a rare occultation in 1969.

In 1981 Neptune is buried in the Milky Way in Ophiuchus and is not well placed for northern observers. At opposition on June 14 Neptune is magnitude +7.7 and 4.38 billion km (29.26 A.U.) distant from Earth.

PLUTO

Pluto, the most distant known planet, was discovered at the Lowell Observatory in 1930 as a result of an extensive search started two decades earlier by Percival Lowell. The faint star-like image was first detected by Clyde Tombaugh by comparing photographs taken on different dates.



The Path of Pluto in 1981. The faintest stars are about magnitude 12–13. The co-ordinates are for 1950.

The most important advance in our knowledge of Pluto since its discovery came in 1978 as a result of routine examinations of photographs of the planet taken at the U.S. Naval Observatory, Flagstaff, Arizona, James W. Christy detected an elongation of Pluto's image on some of the photos which has been interpreted as a satellite at an approximate distance of 17,000 km revolving once every 6.3867 days—identical to the planet's rotation period. This means that the moon is visible only from one hemisphere of Pluto. Calculations made some years ago suggest that this is the only stable orbit a satellite could have with Pluto's slow rotation rate. The moon too would likely have one side constantly turned to Pluto. The name Charon has been proposed for the new-found object.

From the distance and orbital period of Charon, Pluto's mass is estimated to be about one-eighth of the moon's, making it the least massive planet in the solar system. It is also the smallest. Assuming an albedo of 0.5, Pluto's diameter is a mere 3000 km. These figures yield a density of 0.7 that of water. Thus, Pluto is likely a ball of ice with water, methane and ammonia the major constituents. This conclusion is supported by observations in 1976 that revealed frozen methane on much of Pluto's surface, as well as by 1978 speckle interferometry work with the Hale 200" telescope suggesting a 3300 km diameter for Pluto.

Based on the satellite's distance, brightness and revolution period the Naval Observatory astronomers derived a mass ratio of 12 to one for the Pluto-Charon

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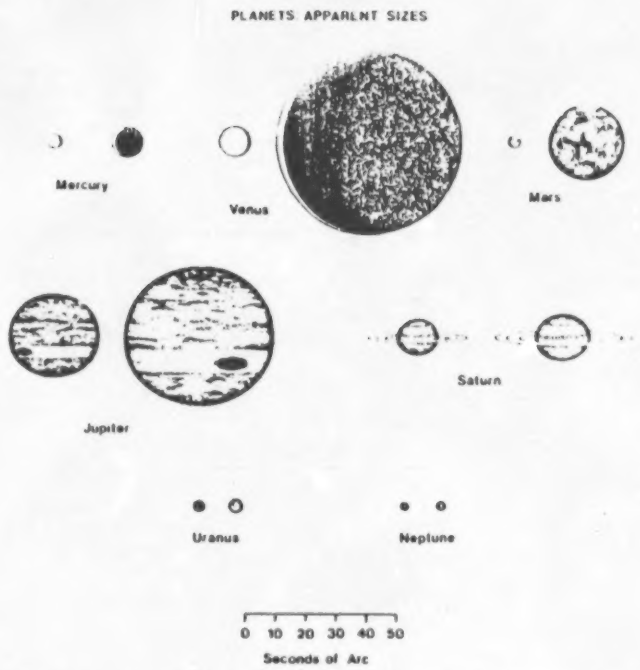

The apparent maximum and minimum observable size of seven planets is illustrated along with characteristic telescopic appearance. The large satellites of Jupiter (not shown) appear smaller than Neptune.

system. Charon is therefore so massive in comparison to Pluto that the two are, in effect, a unique double planet system. No other planet and moon approach this ratio. The Earth-moon system, for comparison, has an 81 to one ratio of masses. Charon's diameter is roughly estimated at 1200 km. Its orbital inclination, which is assumed to coincide with Pluto's axial inclination, is about 105° with respect to the sky.

Pluto now appears to be completely different from the other eight planets. Its unique characteristics include its orbit which is relatively higher inclined and so elliptical that the planet will be closer to the sun than Neptune from 1980 to 1999. Just where such a freak fits into the solar system's origin and evolution is unknown. Perhaps Pluto is the largest member of a group of small ice comet-like structures beyond Neptune.

At opposition on April 13, Pluto's astrometric position is R.A. (1950) $13^h\ 49^m.5$, Dec. (1950) $+7°\ 41'$ and its distance from Earth will be 4.36 billion km (29.10 A.U.). With an apparent magnitude of +13.7, Pluto is a difficult target in moderate-sized amateur telescopes.

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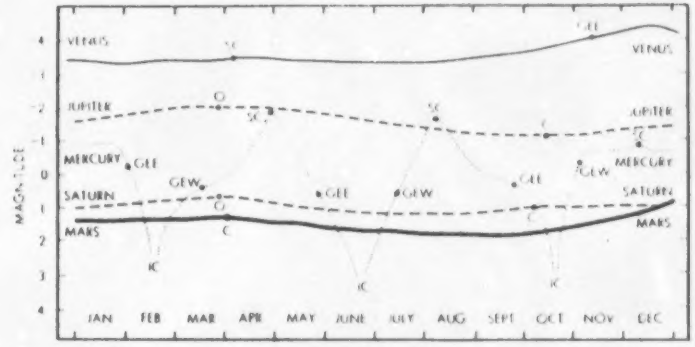

The magnitudes of the planets in 1981. Conjunctions, oppositions and greatest elongations are indicated.

OCCULTATION OF σ SAGITTARII BY VENUS

Occultation of σ Sagittarii by Venus on 1981 November 17: σ Sgr is a B3 star with a visual magnitude of 2.1. At the time of the occultation, Venus will be 47° from the sun, have an angular diameter of 28″ and a magnitude of −4.1. It will be 46% illuminated, the position angle of the mid-point of the illuminated limb being 268°. Thus the disappearance will occur at the dark limb and the reappearance at the bright limb.

The area of visibility will be Newfoundland (very low), Central and South America and the Caribbean, Africa, Europe and S.W. Asia. However only in eastern Europe and S.W. Asia will the event occur after sunset.

The times of disappearance and reappearance, as seen from the western hemisphere, are as follows:

Place	Disappearance Nov. 17				Reappearance Nov. 17			
	U.T.	P.A.	Altitude		U.T.	P.A.	Altitude	
			Star	Sun			Star	Sun
	h m	°	°	°	h m	°	°	°
Bermuda	15 23.6	58	7	38	15 34.1	290	9	38
Caracas	15 22.1	76	18	58	15 33.6	273	20	59
Cerro Tololo	15 23.0	117	31	71	15 32.8	232	34	73
Buenos Aires	15 23.8	117	43	74	15 33.6	231	45	74
Rio de Janeiro	15 23.8	101	54	79	15 35.0	247	57	76

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MAJOR VISUAL METEOR SHOWERS FOR 1981

Shower	Shower Maximum			Radiant				Single Observer Hourly Rate	Velocity	Normal Duration to 1/4 Strength of Max
				Position at Max		Daily Motion				
	Date	E.S.T.	Moon	R.A.	Dec.	R.A.	Dec.			
		h		h m		m			km/sec	days
Quadrantids	Jan. 4	09	NM	15 28	+50			40	41	1.1
Lyrids	Apr. 22	03	FM	18 16	+34	+4.4	0.0	15	48	2
η Aquarids	May 4	09	NM	22 24	+00	+3.6	−0.4	20	65	5
S. δ Aquarids	July 28	12	NM	22 36	−17	+3.4	−0.17	20	41	7
Perseids	Aug. 12	03	FM	03 04	+58	+5.4	+0.12	50	60	4–6
Orionids	Oct. 21	07	LQ	06 20	+15	+4.9	+0.13	25	66	2
S. Taurids	Nov. 5	05	LQ	03 32	+14	+2.7	+0.13	15	28	
Leonids	Nov. 17	01	LQ	10 08	+22	+2.8	−0.42	15	71	
Geminids	Dec. 13	23	FM	07 32	+32	+4.2	0.07	50	35	2–3
Ursids	Dec. 22 (1982)	08	NM	14 28	+76			15	34	1–2
Quadrantids	Jan. 4	15	LQ	15 28	+50			40	41	1.1

A SELECTION OF MINOR VISUAL METEOR SHOWERS

Shower	Dates	Date of Max	Velocity
			km/sec
α Leonids	Feb. 5–Mar. 19	Feb. 26	23
σ Leonids	Mar. 21–May 13	Apr. 17	20
ε Herculids	May 19–June 14	June 3	15
N. δ Aquarids	July 14–Aug. 25	Aug. 12	42
τ Capricornids	July 15–Aug. 10	July 30	23
S. ι Aquarids	July 15–Aug. 25	Aug. 5	34
N. ι Aquarids	July 15–Sept. 20	Aug. 20	31
κ Cygnids	Aug. 9–Oct. 6	Aug. 18	25
S. Piscids	Aug. 31–Nov. 2	Sept. 20	26
N. Piscids	Sept. 25–Oct. 19	Oct. 12	29
N. Taurids	Sept. 19–Dec. 1	Nov. 13	29
Annual Andromedids	Sept. 25–Nov. 12	Oct. 3	18–23
Coma Berenicids	Dec. 12–Jan. 23	–	65

NORTH AMERICAN METEORITE IMPACT SITES

By P. Blyth Robertson

The search for ancient terrestrial meteorite craters, and investigations in the related fields of shock metamorphism and cratering mechanics, have been carried out on a continuing basis since approximately 1550, although a few structures were investigated earlier. In Canada, this research is undertaken largely at the Earth Physics Branch, Dept. Energy, Mines and Resources, and in the United States at the facilities of NASA and the U.S. Geological Survey. Particular aspects of these studies are also carried out at various universities in both countries, and the information in the following table is a compilation from all these sources.

Of the thirty-eight confirmed North American impact structures, which account for almost half of the world's recognized total, meteorite fragments are preserved at only three. In large impacts, where craters greater than approximately 1.5 km in diameter are created, extreme shock pressures and temperatures vapourize or melt the meteorite which subsequently becomes thoroughly mixed with the melted target rocks and is no longer recognizable in its original form. These larger hypervelocity impact craters are therefore identified by the presence of shock metamorphic effects, the characteristic suite of deformation in the target rocks produced by shock pressures exceeding approximately 7 GPa (1 GPa = 10 kilobars). The Holyrood structure, in fact, comprises four sites at the surface where definitive shock features have been recognized, but the circular crater outline is not evident.

In addition to the sites whose impact origin is confirmed by identification of diagnostic shock features, there are approximately twenty structures in Canada and the United States for which an impact origin seems highly probable, but where distinctive evidence of shock metamorphism has not been found.

In the table, sites accessible by road or boat are marked "A" or "B" respectively and those sites where data have been obtained through diamond-drilling or geophysical surveys are signified by "D" and "G", respectively.

Name	Lat.	Long.	Diam. (km)	Age (× 10⁶ yr)	Surface Expression	Visible Geologic Features	
Barringer, Meteor Crater, Ariz.	35 02	111 01	1.2	0.05	rimmed polygonal crater	fragments of "Canyon Diablo" meteorite, highly shocked sandstone, disturbed rocks	A D G
Bee Bluff, Texas	29 05	099 51	2.4	40 ± 10	shallow circ. depression, rim remnants	breccia	A D G
Brent, Ont.	46 05	078 29	3.8	450 ± 30	sediment-filled shallow depression	fracturing	A D G
Carswell, Sask.	58 27	109 30	37	485 ± 50	discontinuous circular ridge	shatter cones, breccia	A D G
Charlevoix, Que.	47 32	070 18	46	360 ± 25	semi-circular trough, central elevation	breccia, shatter cones, impact melt	A D G
Clearwater Lake East, Que.	56 05	074 07	22	290 ± 20	circular lake	breccia, shatter cones, sedimentary float	A D G
Clearwater Lake West, Que.	56 13	074 30	32	290 ± 20	island ring in circular lake		D G
Crooked Creek, Missouri	37 50	091 23	5.6	320 ± 80	oval area of disturbed rocks, shallow marginal depression	breccia, impact melt	D G
Decatur Nile, Missouri	37 54	092 43	6	< 300	slight oval depression	breccia, shatter cones	A D
Deep Bay, Sask.	56 24	102 59	12	100 ± 50	circular bay	breccia, shatter cones, sedimentary float	A D
Flynn Creek, Tenn.	36 16	085 37	3.8	360 ± 20	sediment-filled shallow depression with slight central elevation	breccia, shatter cones, disturbed rocks	A D G
Gow Lake, Sask.	56 27	104 29	5	< 200	lake and central island	breccia	A D G
Haviland, Kansas	37 37	099 05	0.0011	< 0.001	excavated depression	fragments of "Brenham" meteorite	G
Haughton, NWT	75 22	089 40	20	< 20	shallow circular depression	shatter cones, breccia	A G
Holleford, Ont.	44 28	076 38	2.35	550 ± 100	sediment-filled shallow depression	sedimentary fill	A G
Holyrood, Nfld.	47 20	053 10	2.3	500	4 localities of shocked rock	shatter cones, breccia	A
Ile Rouleau, Que.	56 41	073 55	4	< 300	island in central uplift of submerged structure	shatter cones, breccia, dikes	A D G
Kentland, Ind.	40 45	087 24	13	300	central uplift exposed in quarries, rest buried	breccia, shatter cones, disturbed rocks	A
Lac Couture, Que.	60 06	075 18	8	420	circular lake	breccia, float	A
Lac La Moinerie, Que.	56 39	064 36	8	400	lake-filled, partly circular	breccia, float	A
Lake St. Martin, Man.	51 45	098 33	23 × 5	227 ± 41	none, buried and eroded	breccia, float	A G
Lake Wanapitei, Ont.	46 44	080 44	7.5	37 ± 2.5	lake-filled, partly circular	impact melt, breccia	A G
Manicouagan, Que.	51 23	068 42	100	210 ± 32	circumferential lake, central elevation	breccia	B G
Manson, Iowa	42 35	094 31	32	70	none, central elevation buried to 3 km	impact melt, breccia	A D G
Middlesboro, Ky.	36 37	083 44	3.2	300	circular depression	disturbed rocks	A
Mistastin Lake, Lab.	55 53	063 18	28	38 ± 4	elliptical lake and central island	breccia, impact melt	
New Quebec Crater, Que.	61 17	073 40	3.44	< 1.4	rimmed, circular lake	raised rim	G
Nicholson Lake, NWT	60 40	100 41	12.5	450	irregular lake with islands	breccia	G
Odessa, Tex.	31 46	102 30	0.17	0.05	sediment-filled shallow depression, with very slight rim, 4 others, buried and smaller	fragments of "Odessa" meteorite	A D G
Pilot Lake, NWT	60 17	111 01	6	< 300	circular lake	fracturing, breccia, shatter cones	A D G
Redwing Creek, N. Dak.	47 41	100 30	9	200	none, buried	breccia, shatter veins	A D G
Serpent Mound, Ohio	39 02	083 24	6.4	300	circular area of disturbed rock, slight central elevation and surrounding depression		A G
Sierra Madera, Tex.	30 36	102 55	13	100	central hills, annular depression, outer ring of hills	breccia, shatter veins	A D G
Slate Islands, Ont.	48 40	087 00	30	350	islands are central uplift of submerged structure	shatter veins, breccia	A D G
Steen River, Alta.	59 31	117 38	25	95 ± 7	none, buried to 200 metres	dikes	B G
Sudbury, Ont.	46 36	081 11	140	1849 ± 15(?)	elliptical basin	breccia, impact melt	D G
Wells Creek, Tenn.	36 22	087 40	14	200 ± 100	basin with central hills, inner and outer annular valleys and ridges	shatter cones	A D G
West Hawk Lake, Man.	49 46	095 11	2.7	100 ± 50	circular lake	breccia, shatter cones, mylonite	A D G

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